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THIS IS UNEVALUATED INFORMATION. SOURCE GRADINGS ARE DEFINITIVE. APPRAISAL OF CONTENT IS TENTATIVE.

1. Attached for retention is a two-part manual on the Soviet SON-9 (FIRE CAN) radar. The document entitled Antiaircraft Artillery Instruction, Gun-Laying Radar SON-9, is an English translation of a Polish-language manual published by the Ministry of National Defense, Warsaw, 1957. 50X1-HUM

2. Part I (310 pages) is entitled "Design and Functioning of the SON-9 Radar" and Part II (263 pages) is entitled "Operation of the SON-9 Radar". A detailed table of contents is given at the end of each part. 50X1-HUM

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MILITARY/AIR

Text of a Manual: "Gun-Laying Radar SON-9"

MINISTRY OF NATIONAL DEFENCE

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ANTI-AIRCRAFT ARTILLERY INSTRUCTION

GUN-LAYING RADAR SON-9.

Part I - Design and functioning of the set.

Part II - Operation of the set.

WARSAW

1957

INTRODUCTION

The SON-9 radar station is a complicated piece of equipment. A thorough knowledge of the equipment as well as correct operation and maintenance will ensure trouble-free operation and extend its service life.

The first part of the Manual gives a general description of the station, and construction of equipment and units.

The second part contains instructions on the technical operation of the station, tuning and adjustment of its equipment and units, maintenance and care, fault-finding and repair procedure. Voltage and resistance charts and oscillograms of voltages in reference points of the units are also given.

The appendices include the list of spare parts (ZIP), the table of electric vacuum devices, description of the URAL-2 device, specification to key diagrams of the units and a table of transformer and choke data.

Key diagrams of separate systems, devices and units of the station, diagrams of interunit connections, cables, a block diagram of the station and all appendices are given in the Album, which is part and parcel of the Manual.

References for diagrams and appendices appearing in the Album are given in brackets (See Album or drawing).

P A R T I

DESIGN AND FUNCTIONING OF RADAR STATION SON-9

C h a p t e r I

GENERAL

1. PURPOSE OF STATION

The mobile gun laying radar SON-9 in conjunction with fire-control director PUAZO-6 (or PUAZO-5) is designed for use with small and medium calibre anti-aircraft artillery. The SON-9 can be used also with PUAZO-3

.../or PUAZO-4,

or PUAZO-4, but in these cases computor LSPPM must be used.

The SON-9 detects air targets at a distance of not less than 50 km. irrespective of visibility and weather, continuously determines target co-ordinates (azimuth, elevation angle and slant range) and transmits them to the fire-control director and the searchlight.

The SON-9 station during combat operation includes a trailer with radar equipment and a tractor (truck ZIS-151), on which is mounted a power unit of the APG-15 type, spares and other equipment.

The general view of the station with the tractor in a travelling position is shown in Fig.1, and in a set-up position - in Fig.2.

2. BASIC SPECIFICATIONS OF STATION

The station enables targets to be detected and tracked irrespective of visibility and weather conditions.

The main specifications of the station are as follows:

1. Frequency range: 2700 to 2860 Mc/sec. (10.5 to 11.1 cm).

2. Power in the pulse: about 250 kW.

3. Detection range during manual sector scanning of a medium bomber (Type Tu-2) flying at an altitude of 4000 m. is not less than 50 km.

4. Range of automatic tracking of a medium bomber (Type Tu-2) is not less than 35 km.

5. Limits of operation:

   in azimuth .... unlimited

   in elevation angle .... from -0-50 to +14-50

6. Mean error in determining target data during automatic tracking:

   in range .... 20 m. within 1 - 35 km.

   in azimuth .... 0-01.6 within 60-00 at elevation angle values from +1-00 to +13-00

   in elevation .... 0-02 within +1-00 to 13-00

.../7. Resolution

7. Resolution of the radar station in slant range:

during manual tracking .... 125 m.

during automatic tracking ..... 200 m.

8. Type of antenna .... parabolic reflector (D = 1.5 m.) with asymmetrical rotating dipole

9. Half-power width of the directional radiation pattern: 0-83 ± 0-08

10. Pulse duration: 0.5 microsecond.

11. Pulse repetition frequency: 1875 c/sec.

12. Intermediate frequency: 30 Mc/sec.

13. Intermediate frequency amplification in the range measuring channel: not less than 75,000.

14. Intermediate frequency pass-band width: 3.6 Mc/sec.

15. Intermediate frequency amplification in the automatic tracking channel: not less than 200,000.

16. Intermediate frequency pass-band width in the automatic tracking channel: 2.2 to 2.8 Mc/sec.

17. Supply voltage:

single-phase current .... 110 V, 427 c.p.s.

three-phase current .... 220 V, 50 c.p.s.

18. Power consumed from:

110 V, 427 c.p.s. mains .... 2900 VA

220 V, 50 c.p.s. mains .... 7000 VA

19. Sector scanning:

in azimuth .... 4-00 - 9-00

in elevation angle .... 1-70 - 2-10

20. Radar siting time .... 15 min.

21. Connection time of sited radar 3.5 min.

22. Weight of radar trailer .... approximately 7 tons

23. Weight of complete tractor ... approximately 8 tons

.../24. Dimensions

24. Dimensions of trailer cabin in travelling position:

length with a drawbar .... 6500 mm

length without a drawbar ...... 5000 mm

height .... 3200 mm

width .... 2400 mm

25. Maximum transportation speed:

on main roads .... 40 km/hr

on country roads .... 25 km/hr

26. The station may be transported by railways with freight dimension "O".

3. SIMPLIFIED BLOCK-DIAGRAM OF STATION AND PRINCIPLE OF DETERMINING COORDINATES

The station produces powerful short-time electromagnetic pulses of high frequency, which are radiated into space by the antenna.

If the beam of electromagnetic energy strikes an object, for example an aircraft, on its way, a portion of this energy will be reflected back to the station.

The reflected pulses picked up by the antenna are furnished to the receiving equipment through the feeder system.

The pulses converted and amplified in the receiving system are fed to the cathode-ray tubes of indicators, forming corresponding target marks on their screens, as well as to the antenna positioning system and automatic range finder (during automatic tracking) which ensure continuous matching of the antenna axis with the direction to the selected target and automatic determining of the slant range and the target angular data.

The equipment of the SON-9 has the following basic systems (See Fig.3):

(a) transmitting system;

(b) antenna-feeder system;

(c) receiving system;

(d) range-measuring system;

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.../(e) plan-positon

(e) plan-position indicator system;

(f) antenna positioning system;

(g) data transmitting system;

(h) power supply system.

The transmitting system is designed to produce powerful short-time electromagnetic pulses of high frequency which are radiated into space by the antenna.

The transmitting system includes a driver unit and a modulator-oscillator unit composed of a modulator, a magnetron oscillator and a high-voltage rectifier.

The driver is fed with trigger pulses produced in the range finding system. These pulses are of about 1.5 microsecond duration and of 1875 c/sec repetition frequency.

The trigger pulses are used in the driver to generate voltage pulses of 0.5 microsecond duration which are amplified and furnished to the modulator. Here they are converted into powerful high-voltage pulses with an amplitude of about 20 kV and are fed out to the magnetron.

The magnetron produces powerful pulses of electromagnetic oscillations of 0.5 microsecond duration and of 1875 c/sec repetition frequency. The oscillation frequency depends upon the type of the magnetron employed in the station and is in the range of 2700 to 2860 Mc/sec.

The station is provided with magnetrons, types MI-18, MI-19, MI-20 and MI-21. Power of oscillations during the pulse is about 250 kW. The oscillations produced by the magnetron are furnished to the antenna-feeder system.

The antenna-feeder system is designed to transmit electromagnetic energy generated by the transmitter, radiate it into space in the prescribed direction as well as to pick up signals reflected from the target and apply them to the receiver input. The station uses one antenna for transmitting and receiving.

.../The antenna-feeder

The antenna-feeder system includes: a high-frequency coaxial feeder, an antenna change-over switch and an antenna consisting of the antenna head and a parabolic reflector.

Energy of high-frequency oscillations produced by the magnetron oscillator is supplied through the feeder to the antenna head and a radiator situated in the focal plane of the parabolic reflector. In intervals between the transmitter pulses the echo signal energy is applied through the same feeder from the antenna head to the input of the receiving system. To facilitate the antenna rotation the feeder line is provided with rotating joints arranged on those feeder sections that run along the appropriate rotation axis of the antenna.

The antenna change-over switch performs the following two functions. When the magnetron oscillator is operating it blocks the path of powerful pulses from the magnetron oscillator output to the receiver and ensures practically complete transmission of radio-frequency energy from the magnetron oscillator to the antenna. In intervals between the transmitter pulses when signals reflected from the targets return to the station it ensures complete transmission of energy of these signals from the antenna to the receiver input thus preventing useless dissipation of this energy in the transmitter circuits.

The station antenna due to the use of the parabolic reflector of 1.5 m diameter possesses sharp directivity both during transmission and reception. This means that during transmission its energy is radiated in a narrow sector of space and during reception of electromagnetic oscillations the antenna is fed with the signals from those targets which are within the same sector.

The main characteristic of any directional antenna is its diagram or so-called radiation pattern which represents graphically power distribution during antenna radiation in various directions during transmission and

.../sensitivity of

sensitivity of an antenna to the signals coming from various directions during reception.

The width of the radiation pattern of the SON-9 antenna is 0-83. It is determined as an angle between two directions, the radiating power for which constitutes half the power in relation to its maximum radiation (See Fig.4).

To provide accurate continuous tracking of the target during automatic tracking the axis of the radiation pattern (i.e. the direction of maximum radiation) is displaced with respect to the geometrical axis of the antenna (the axis coming through the focus and geometrical centre of the paraboloid) through an angle of 0-23 (Fig.5) and the entire radiation pattern, when the station is functioning, is continuously rotated about the geometrical axis of the antenna at a speed of 1440 r.p.m. (24 r.p.s.). In this case the axis of the radiation pattern describes a cone in space. The antenna geometrical axis coincides with the electrical axis of the antenna during automatic tracking in angular coordinates (the antenna electrical axis - the direction from the antenna to the target being tracked at accurate bearing of the target).

The axis of the radiation pattern is displaced in relation to the geometrical axis of the antenna due to the radiator asymmetry and the radiation pattern rotation is achieved by rotating the antenna head about its axis with the help of an electric motor which simultaneously rotates a reference voltage generator (GON) included in the antenna positioning system.

The receiving system is designed for converting the signals reflected from the target and picked up by the antenna and for further amplification to the value required for normal operation of the range and plan-position indicators, the antenna positioning system and the automatic range finder unit.

The receiving system consists of crystal mixers of the signal, automatic frequency control (AFC), an intermediate-frequency preamplifier (IFP) and an amplifier of the range- and automatic tracking channel.

.../The receiving

The receiving system employs a superheterodyne circuit.

The reflected signals picked up by the antenna are furnished through the feeder line and the antenna change-over switch to the crystal mixer which is continuously fed with A.C. voltage of high frequency from the centimetre heterodyne (klystron) located in the intermediate-frequency preamplifier stage. The heterodyne frequency is higher than that of the transmitter, i.e. the frequency of the picked-up signals by 30 Mc/sec.

Simultaneous action of these two high-frequency voltages on a non-linear element, i.e. the crystal mixer, results in development of intermediate (differential) voltage of 30 Mc/sec frequency at the mixer output. Each intermediate frequency pulse duration is the same as the incoming pulse duration, and equals 0.5 microsecond.

From the crystal mixer the I.F. pulse voltage is applied to the I.F. preamplifier through the radio-frequency cable. This voltage is amplified in the preamplifier by three stages and through the radio-frequency cable is applied to the input of the automatic tracking channel amplifier. Here the signals are amplified first in one common intermediate frequency amplifier channel (four stages) and then in two amplifier channels - in range and automatic tracking channels. From the output of the automatic tracking channel the signals are coupled to the automatic tracking unit of the antenna positioning system, while from the range channel - to the input of the range channel amplifier unit of the receiving system.

All signals which are being furnished to the input of the receiving system are amplified in the amplifier unit of the range channel. The amplifier output is coupled to the range and very narrow gate indicators plan-position indicator system and to the automatic range finder unit to control its operation during automatic measurements of the slant range to the targets. The range and plan-position indicators are devised to observe the signals reflected from all targets and local objects that are at the given moment within the area swept by the antenna.

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.../The receiver

The receiver automatic tracking channel is completely cut off most of the time. It is opened only at the time of arrival of the signals reflected from the target selected by the operator.

The signals reflected from the target are passed from the output of the automatic tracking channel amplifier to the antenna positioning system which by the action of these voltage pulses provides continuous automatic matching of the antenna axis with the direction to the target being tracked.

The automatic frequency control circuit in the I.F. preamplifier unit produces voltages which control the klystron frequency in such a manner that when the difference between the klystron and magnetron frequencies deviates from 30 Mc/sec, the klystron frequency changes automatically and the differential (intermediate) frequency remains constant. This compensates for unstability of the klystron and magnetron carrier frequency and ensures constancy of the receiving system sensitivity.

The range measuring system is designed to measure the target range continuously and accurately and to synchronize the operation of other systems and units of the station.

The range measuring system is composed of the following components: a range and very narrow gate indicator unit, a range unit, an automatic range finder unit, a range mechanism unit.

The range measuring system is supplied from two common supply units for the range measuring system and the plan-position indicator system.

Determination of the slant range, i.e. measurement of the time interval between the emission of the signal and receipt of the corresponding echo is achieved by aligning the reflected signal with electronic markers whose time delay in relation to trigger pulses can be determined with a high degree of accuracy.

Having matched the electronic markers with the echo pulse on the cathode-ray tubes of the range indicator unit, the operator can read the target slant range off the scales of the range mechanism unit.

The range is measured with a moving target, therefore the continuous matching of the electronic markers with the reflected signal is done automatically with the help of the automatic range finder or manually by the operator.

To synchronize the operation of all elements of the range measuring system the plan-position indicator system, the transmitter and the range unit is provided with a sine-wave oscillator whose frequency (74.955 Kc/s) is crystal controlled. The crystal oscillator voltage is applied to the step divider circuit which produces voltages with frequencies five, twenty and forty times smaller than the frequency of the crystal oscillator, i.e. approximately 15 Kc/s, 3.75 Kc/s and 1.875 Kc/s.

To obtain a circular sweep on the fine-range indicator use is made of two sine-wave voltages having the frequency of the crystal oscillator, shifted in phase by 90° in relation to each other. These two voltages applied to two pairs of deflecting plates of the tube cause the electronic beam to trace a circle on the tube screen. The time required for the beam to make a circle is 13.3 microseconds, which corresponds to a range of 2 km.

To obtain a circular sweep on the coarse-range indicator use is made of two voltages of 3.75 Kc/s which are 90° out of phase. The voltages applied to the deflecting plates of the tube make the electronic beam trace a circle on the screen; the time required for the beam to make a circle is increased 20 times as compared with the time required for the fine-range tube and, consequently, corresponds to a range of 40 km.

The voltage pulses of 1.875 Kc/sec frequency produced in the range unit are employed for forming trigger pulses which control the transmitter and the plan-position indicator system. Besides, voltage of 1.875 Kc/sec frequency is used for forming gate pulses whose delay in relation to trigger pulses can be varied.

The transmitter sends its pulses of 1.875 Kc/sec frequency every two revolutions of the sweep on the coarse-range indicator and every 40

revolutions of the sweep on the fine-range indicator. The indicators are set in such a position that each time the pulse is transmitted the electronic beams in both tubes are in upper points of the sweep trace (at zero point). The echo pulses are furnished from the output of the receiver range channel to the central deflecting electrodes of both range indicators. These pulses cause outward radial deflections on the sweep trace.

Thus the screen of the coarse-range indicator displays the station transmitter pulses as a radial pip in the upper initial point of the sweep trace, whereas radial pips caused by the target echoes are arranged on the sweep circle at corresponding distances from the transmitter pulse.

The echoes from the targets the range difference between which amounts to 40 km. are located in the same point of the sweep. For example, the echoes from the targets located at distances of 10 and 50 km. from the station appear on the sweep trace on the 10 km. range mark after each transmitter pulse during the first and second revolution of the sweep.

To avoid possible errors in determining the target range the sweep of the coarse-range indicator is brightened by pulses generated in the range unit. The gating pulse duration is approximately 260 microseconds, i.e. slightly less than the time required for one revolution of the sweep on the screen of the coarse-range indicator. Thus the indicator screen is brightened only for the time of the first or second revolution of the sweep after each transmitter pulse depending upon the position of the switch 0 - 40 km. - 40 - 80 km.

To form the electronic marker of the coarse-range indicator use is made of strobe pulses which brighten an additional area on the sweep, i.e. a movable electronic marker. To determine the range it is necessary to match the movable electronic marker with the target echo by operating the range knob and to read the indication on the coarse-range scale of the range mechanism. However, the reading will be inaccurate because first, the

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.../linearity in

linearity in changing the strobe pulse delay depending on the turn of the range mechanism coarse scale is sufficiently high, and secondly, the electronic marker fails to be matched accurately with the target echo on the coarse-range indicator due to its small scale.

To determine the range accurately provision is made in the system for a second reference pulse - the electronic marker of the fine-range indicator which is formed with the help of the crystal oscillator voltage. This voltage is applied to a phase-shifting circuit. The main component of the circuit is a phase shifter, whose rotor is kinematically connected to the range mechanism fine scale. The change of voltage phase at the phase shifter output is linearly dependent upon the turn of its rotor, i.e. the turn of the range mechanism fine scale. The crystal oscillator voltage shifted in phase is used to form two short pulses which, applied to the fine-range indicator, form two darkened sectors, or the fine-range electronic marker.

When determining the range it is necessary to set the electronic marker on the fine-range indicator symmetrically relative to the echo signal selected on the coarse-range indicator, i.e. to set in such a way, that the end of the first and the beginning of the second mark of the electronic marker are at the same level to the sweep trace, then to take a reading on the range mechanism fine scale always rounding off the smaller values.

If the electronic beam of the fine-range indicator were visible all the time, large errors might occur when determining the range, because the same sweep spot of the fine-range indicator would display the signals reflected from several targets the distances between which differ from each other by multiples of two kilometres. To avoid superimposing echo signals from several targets the fine-range indicator is brightened by pulses of lower than 13.3 microseconds duration, i.e. lower than the time required for one revolution of the sweep.

For gating of the fine-range indicator use is made of strobe pulses. As was mentioned above the strobe pulse delay in relation to trigger pulses

.../always corresponds

always corresponds to the reading on the range mechanism coarse scale. If the scale readings are increased from 0 to 40 km. by operating the range knob, the strobe pulse delay in relation to trigger pulses will increase from 0 to 266 microseconds.

Thus, depending upon the scale readings the strobe pulse brightens on the fine-range indicator the portion of the first, second, third and so on up to the twentieth sweep revolution inclusive after the transmitter pulse. Consequently the screen of the fine-range indicator can display a signal from that target which coincides with the electronic marker on the coarse-range indicator and whose range corresponds to the reading on the range mechanism scales.

When tracking the target its slant range is determined by continuously matching the electronic markers with the target echo. The elements for controlling the electronic markers are kinematically connected between each other and have a common drive. Besides the manual range tracking, when the electronic markers are matched with the target echoes by rotating manually the common drive with the help of the range knob, provision is made for automatic tracking. In this case the common drive is rotated by the automatic tracking motor whose speed is controlled by the automatic range finder.

The automatic range finder produces two pulses that follow in succession (called split gate pulses) which are always synchronized with the reference pulse - the electronic marker of the fine-range indicator. Besides, the automatic range finder is furnished with the target echoes from the receiver range channel output.

The time-phase of the echo signals and reference pulses is compared in a special stage of the automatic range finder (called an error signal time discriminator.) The voltage at the discriminator output depends on the mutual time-phase of the reference pulses and the target echo. The polarity of this voltage depends on whether the reference pulses lag behind or lead the target echo, whereas its value is determined by the degree of lagging behind or leading.

When the electronic markers are matched with the echo from the target selected for tracking on the indicators, the reference pulses in the automatic range finder are arranged symmetrically with respect to the echo from the same target - there is no error voltage at the discriminator output. This error signal in the course of automatic range tracking is amplified and converted into an A.C. voltage of 50 c.p.s.; this voltage controls the automatic tracking motor, the reference pulses in the automatic range finder and electronic markers on the fine-range tube being arranged symmetrically in relation to the echo from the target being tracked.

The common drive of the range mechanism is connected with coarse and fine-range transmitting selsyns which aid in conveying continuously the slant range data to the anti-aircraft fire director and other devices situated outside the station.

To ensure tracking of the selected target in angular coordinates (without interference from other targets located in close proximity) use is made of short pulses of 0.3 microseconds duration called very narrow gate pulses to control the operation of the receiver automatic tracking channel. The time-phase of the very narrow gate pulses is always dependent upon the position of the electronic marker on the fine-range indicator. When matching electronic markers with the target echo on the range indicators, the very narrow gate pulses open the gated intermediate-frequency amplifier stage of the receiver automatic tracking channel at the moment the echo from the selected target is applied to the receiver input.

Controlling the receiver automatic tracking channel by very narrow gate pulses makes it possible to track the target without interference from other targets which are within the antenna scanning area if the difference between the slant ranges of these targets and the selected target exceeds approximately 125 m.

The plan-position indicator system is designed to detect and observe targets in the area being scanned as well as to determine their coordinates

with an accuracy sufficient for automatic target tracking.

The plan-position indicator system includes a plan-position indicator unit and a plan-position indicator transmitting selsyn housed in the antenna pedestal.

The plan-position indicator system is fed from the supply unit of the range measuring and plan-position indicator systems.

The plan-position indicator utilizes a magnetic cathode-ray tube. The tube deflecting coil passes saw-tooth current pulses. The magnetic field induced by the current pulses causes the electronic beam to deflect from the centre to the edge of the screen, thus forming a radial sweep trace. The sweep is triggered by trigger pulses of 1.875 Kc/sec frequency produced in the range unit. The same pulses are used for triggering the station transmitter which synchronizes the moment of the sweep start on the plan-position indicator screen with the emission of the transmitter pulse.

With the help of the synchro drive circuit of the deflecting coil the position of the radial sweep changes depending on the antenna rotation angle in azimuth. During continuous rotation of the antenna in azimuth, i.e. during circular scanning, the radial sweep on the tube screen rotates in synchronism with the antenna about the screen centre. During sector scanning the radial sweep on the screen while moving in synchronism with the rotation of the antenna in azimuth, oscillates in a definite sector.

From the output of the receiver range channel amplifier the echo pulses are furnished to the control electrode of the cathode-ray tube, thus increasing the brightness of the radial sweep in appropriate points. During continuous circular rotation in azimuth bright spots from each given target appear on the sweep only when the target is within the radiation area. As a result the mark from the point target on the tube screen is essentially an echo-arc formed by bright spots on the rotating sweep. The angle subtended by the echo-arc equals the antenna pattern flare. The distance

.../between the

between the echo-arc and the tube screen centre given in a definite scale corresponds to the slant range of the target.

At the edge of the tube screen is an azimuth scale with angular divisions (from 0 to 60-00). Due to synchronous rotation of the sweep and antenna in azimuth, the sweep always indicates an azimuth in which the antenna is directed. The target azimuth is determined by taking the reading off the azimuth scale, which corresponds to the mid-point of the echo-arc representing the given target.

In order to observe the signals returned from various targets in the area surrounding the station the plan-position indicator utilizes a cathode-ray tube with a long-persistance screen. Any bright spot appearing on the screen remains visible for about 10 seconds. Thus during circular scanning when the antenna rotates in azimuth at a speed of about 12 r.p.m. the tube screen continuously displays the target echoes and local objects.

The plan-position indicator unit is provided with a range marker stage whose operation is controlled by voltage pulses of 15 Kc/s furnished by the range unit. The range pulses create bright spots on the radial sweep, which during continuous rotation merge into range concentric rings. The distance between the adjacent range rings corresponds to 10 km. of slant range.

The slant range of the target is determined on the screen of the plan-position indicator by the position of the target echo in relation to the range rings.

The antenna positioning system serves to control the antenna position, which can be changed by rotating the antenna about the vertical axis (rotation in azimuth) and about the horizontal axis (rotation in elevation). The system permits the following three modes of operation to be used (depending on how the antenna positioning is carried out):- automatic circular or sector scanning, manual control and automatic target tracking.

.../The first

The first mode of operation is used to observe the area surrounding the station on the P.P.I. or in a selected sector.

The second mode of operation is used to control manually the antenna position, to orient the antenna by the target designation data and to follow the target before changing over to automatic tracking.

The third mode of operation is used to determine accurately the coordinates of the target being tracked. In this case the azimuth and elevation angle are determined automatically, but the range - automatically or manually.

Besides, provision is made in the station SON-9 for reception of target designation data from the circular scanning station and for remote control of the antenna position from the anti-aircraft fire director PUAZO-6. In the latter case the antenna rotates in synchronism with the sighting column of the anti-aircraft fire director PUAZO-6 while the target range is determined by the station automatically or manually.

During circular (or sector) scanning the antenna can rotate (or oscillate) in azimuth with tilting up and down of the antenna in elevation, as well as at constant elevation which is set by the operator.

During manual control the antenna may be controlled in azimuth and elevation with the help of handwheels.

During automatic tracking the antenna automatically follows the target when its angular coordinates are changed.

The antenna positioning system is composed of the following units and assemblies:

1. An automatic tracking unit.
2. An azimuth and elevation tracking unit.
3. An antenna control unit.
4. Amplidynes EMU-5.
5. Azimuth and elevation drive motors.

.../6. An antenna

6. An antenna pedestal.

7. A supply unit of drive-motor field windings.

8. A reference voltage generator (GON).

During automatic tracking use is made of the equisignal zone principle which consists in the following.

As was mentioned above the antenna radiation pattern (direction of maximum radiation) is deflected from the antenna geometrical axis by an angle of 0-23.

When the station is functioning the antenna head and consequently, the radiation pattern are continuously rotating about the geometrical axis at a speed of 24 r.p.m. In this case the radiation pattern axis describes a cone in space. During rotation of the antenna head the point of intersection of the radiation pattern with an imaginary plane passing through the target and at right angles to the antenna geometrical axis (the so-called image plane) will move along the circumference as shown in Fig.6. The same figure represents four typical positions of the radiation pattern: extreme top, right, lower and left positions. Points A, B, C, and D are respectively the points of intersection of the radiation pattern axis with the image plane for these four positions of the pattern.

If the target is in point O, i.e. on the antenna geometrical axis, then at any position of the radiation pattern the value of the signal reflected from this target remains constant and proportional to section ab on the radiation pattern. Therefore the direction to point O is called the direction of equisignal zone or electrical axis of the antenna. Fig.7, a shows voltage pulses of the target echoes.

If the target moves from point O to point C (See Fig.6) the value of the target echoes depends upon the position of the radiation pattern rotating in space at a speed of 24 r.p.m. The value of the target echoes is maximum in the case when the radiation pattern axis is deflected from the antenna

.../electrical axis

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electrical axis (equisignal direction) towards the target displacement (direction OC). The value of the target echoes is minimum when the radiation pattern axis is deflected from the antenna electrical axis in the direction opposite to the target displacement. Thus when the radiation pattern rotates, the value of echoes changes with a frequency of 24 c.p.s. (Fig.7, b).

The magnitude of the echo variation (modulation factor) is proportional to the antenna deflection from the direction to the target or to the so-called sighting error δ. Thus if there is a sighting error, the echo signals are modulated. These signals are picked-up by the antenna, amplified by the receiver and are detected. As a result low-frequency A.C. voltage is obtained which varies with the modulation frequency of the echo signals (24 c.p.s.). This voltage is called the error voltage.

Thus, if the antenna is pointed exactly at the target the echo signals will not be modulated (Fig.7, a) and after they have been detected the error voltage will be zero. The amplitude of the error voltage is proportional to the value of the sighting error while the phase (in relation, for instance, to the moment the beam passes through the extreme left-hand position when it is rotated in space) characterizes the magnitude of the target deflection in azimuth and elevation.

If the error voltage phase equals 0 or 180° the target is deflected only in azimuth. If the phase of this voltage equals 90° or 270°, the target is deflected in elevation. At intermediate values of the error voltage phase the target is simultaneously deflected in azimuth and elevation, the more the phase differs from zero or 180° the more the deflection of the target in elevation and the less in azimuth.

In order to aim the antenna at the target (to align its geometrical axis with the direction to the target), it is necessary to turn the antenna in azimuth through angle $\Delta\beta$ (in the inclined plane) and through angle $\Delta\varepsilon$

.../in elevation

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in elevation (Fig.6). To rotate the antenna, the drive motors rotating the antenna in azimuth and elevation should be fed with control voltages proportional to deflections in azimuth $\Delta\beta$ and elevation $\Delta\varepsilon$, respectively. Therefore the error voltage should be divided into two components so that the amplitude of one is proportional to the value of the target deflection in azimuth $\Delta\beta$ while the amplitude of the other component - to the value of the target deflection in elevation $\Delta\varepsilon$.

The error voltage is divided into the two components in the azimuth and elevation tracking unit by means of two voltages produced by the reference voltage generator.

The reference voltage generator is directly coupled to the electric motor rotating the dipole and develops two voltages shifted in phase by 90° in relation to each other (Fig.8). The frequency of these voltages as well as that of the error voltage is determined by the speed of the dipole rotation and amounts to 24 c.p.s.

The error voltage and reference voltages are simultaneously applied to the commutator stages of the tracking unit to produce two control voltages.

One voltage, i.e. azimuth voltage, is obtained as a result of interaction of the error voltage and azimuth reference voltage (Fig.9); the voltage is dependent on that component of the error voltage which has been obtained due to the target displacement in azimuth through angle $\Delta\beta$.

The second voltage, i.e. elevation voltage, is obtained as a result of interaction of the error voltage and elevation reference voltage (Fig.9); the voltage is dependent on that component of the error voltage which has been obtained due to the target displacement in elevation through angle $\Delta\varepsilon$.

The control voltages are amplified in the amplification and amplidynes and after that are applied to the drive motors rotating the antenna in azimuth and elevation.

The direction the drive motors are rotating is such that with the error voltage applied the antenna moves in the direction of the target,

.../until its

until its geometrical axis is aligned with the target direction. Then the error signal equals zero and so do the control voltages.

When the target moves the error signal appears again, control voltages will be developed in the azimuth and elevation channels and the drive motor will move the antenna again toward the target.

During continuous movement of the target the radar antenna will automatically follow the target.

During manual control the azimuth and elevation channels are fed with two independent error voltages produced by selsyn-transformer circuits. The azimuth channel is supplied with error voltage produced by the transmitting selsyn and the azimuth selsyn-transformer whereas the elevation channel with error voltage produced by the transmitting selsyn and the elevation selsyn-transformer. Instead of two reference voltages from the reference voltage generator the both channels are fed with one common voltage of 50 c.p.s. obtained from the station supply circuit.

The azimuth and elevation transmitting selsyns are accommodated in the antenna control unit and are kinematically coupled with the appropriate controls situated on the front panel of the unit. By rotating these controls the operator can create independent error voltages and, consequently, move the antenna in azimuth or elevation.

The searching differs from the manual control operation in that the transmitting selsyns of the antenna control unit are not rotated manually with the help of handwheels but are driven by the motor housed in the antenna control unit. Rotation from this motor may be imparted to either the azimuth transmitting selsyn or simultaneously through a special set of gears to the elevation transmitting selsyn.

The operator sets the position of the azimuth and elevation scanning sectors with the help of azimuth and elevation handwheels of the antenna control unit.

.../The data

The data transmitting system is designed for automatic continuous transmission of the target data produced by the station to the station display units, anti-aircraft fire director PUAZO-6 and other receivers which may be located outside the station. In addition, the system includes a number of components which make it possible to receive the target designation data from the outside equipment (from the warning station, anti-aircraft fire director PUAZO-6).

Power supply system. The station is supplied from a power unit, type APG-15, with A.C. voltage of 220 V, 50 c.p.s. and A.C. voltage of 110 V, 427 c.p.s.

In addition the station can operate from the three-phase 220 V, 50 c.p.s. mains. In this case 220 V, 50 c.p.s. are fed to the station through the commutation circuits of the power unit, whereas 110 V, 427 c.p.s. are produced by the generator mounted on the unit, the generator being supplied from three-phase 220 V A.C. mains.

4. STATION DESIGN

The equipment of the SON-9 station, is mounted in the trailer body (Fig.10) which is towed by a ZIS-151 truck. The trailer body has a two-sided door on the right side, a horizontally hung rear door, and two windows on the right and left sides of the body. The front wall has a hatch through which an automatic air dryer is installed. The top of the body carries a dome which covers the antenna when the station is in travelling position. When the station is set-up, the dome is removed from the body top and its halves are placed near the station.

The trailer chassis is provided with pneumatic brakes actuated from the truck. For levelling the trailer, the chassis is equipped with four jacks.

The body has lighting, a stove and ventilation.

The rear part of the body accommodates control desk 18 (See Fig.10) which incorporates several units. Located to the right of the control desk,

.../above the

above the wheel house frame, is a control unit, while to the left of the control desk the locker for spare parts, tools and accessories (ZIP) and a voltammeter AVO. Under the control desk is located control panel 20. The front part of the body houses transmitter cabinet 5 with a high-voltage rectifier and antenna pedestal 6, arranged on it. The cabinet for amplidynes 2 and 3 is installed above the left-hand front wheel house frame. The rack mounts air dryer 4. At the front wall transmitter cooling fan 1 is mounted on the floor.

To the right of the entrance door on the body wall are fire extinguishers and a lighting board.

On the left-hand body wall under the window is fixed receiving selsyn unit 16, to the right of the window is stove 15. Between the stove and the amplidyne cabinet on the body wall are located: an echo box, below is a bracket with antenna heads, closer to the stove is the radar operator's folding chair 14 and the telephone operator's chair. The bracket under the telephone operator's table mounts telephone set 21. Built into the left-hand body wall are outer connection boards 24 of the station. The equipment whose operation is affected by jolting during transportation (main control desk, control unit, echo box) is mounted on rubber shock absorbers.

The main control desk (Figs 11 and 12) is built in the form of a cabinet which houses the various units.

The units are secured to the control desk with the help of special retainer bolts. To prevent insertion of a unit into a wrong compartment provision is made for mechanical interlocking.

The front panels of the units carry control and tuning elements (knobs, screw-driver operated shafts, switches, test jacks, etc.) as well as indicators which aid in checking the operation of the station. The units are connected with the help of knife-type connectors.

All connecting wiring arranged on the back of the unit is covered by three removable shields located on the rear side of the frame. The units are marked with corresponding numbers.

The transmitting system is mounted on retractable chassis which is pushed into transmitter cabinet 5 (See Fig.10).

The transmitter cabinet is reinforced welded structure with a top-mounted steel plate which carries the antenna pedestal. The cabinet is designed as a base for the antenna pedestal.

The modulator-oscillator unit housing carries the driver unit and the intermediate-frequency preamplifier unit of the receiving system. These units are put into the modulator housing on the side of the front panel and are held in place in the same way as the main control desk units. The modulator-oscillator unit housing is mounted on skids which facilitates its withdrawl.

The modulator-oscillator unit housing is bolted on to the rear part of the transmitter cabinet.

The chassis is cushioned by means of shock absorbers.

The right-hand upper corner of the housing accommodates the magnetron, the antenna change-over switch and the magnetron heater transformer.

The magnetron and the antenna change-over switch are secured on a common plate which is rigidly bolted on to the antenna pedestal foundation. The transmitter components are cooled by exhaust fan 1 located in the trailer body behind the transmitter. The magnetron and modulator valves are cooled by the air forced by the fan located inside the transmitter. To provide free access to all transmitter units the cabinet plating is provided with six small doors. In addition, the panel covering the magnetron is hinged. Protection of personnel against high voltage is achieved by interlocks mounted on each hinged door and the relay of the transmitter cabinet.

The amplidynes are located above the left-hand wheel house frame in the cabinet.

To reduce noise the cabinet is covered with a sound proof shield which is screwed to the cabinet. For cooling the amplidynes the front body wall is provided with a vent hole.

Mounted above the left-hand rear wheel house frame is a storage battery supplying the emergency lighting circuit of the trailer body.

5. LIST OF STANDARD EQUIPMENT

The Table below lists a number of units and assemblies included in the station standard equipment and their designation.

Name of unit	Designation
Transmitting System	
Driver unit	23
Modulator-oscillator unit	25
Receiving System	
Intermediate-frequency preamplifier	22
Automatic tracking channel amplifier unit	1
Range channel amplifier unit	2
Antenna-Feeder System	
Antenna change-over switch	28
Feeder system	-
Range-Measuring System	
Range unit	8
Range-mechanism unit	4
Range and very narrow gate indicator unit	3
Automatic range finder unit	7
Plan-Position Indicator System	
Plan-position indicator unit	11
Supply unit of plan-position indicator and range-measuring systems	5
Range-measuring system supply unit	9

.../Antenna Positioning

Name of unit	Designation
Antenna Positioning System	
Automatic tracking unit	6
Azimuth and elevation automatic tracking unit	10
Antenna control unit	12
Amplidyne cabinet	–
Supply unit of drive-motor field windings	66
Antenna pedestal	32
Data Transmitting System	
Receiving selsyn unit	44
Outer board	33
Supply System	
Control unit	31
Control panel	13

Standard letter designations and symbols of radio components and elements are used on key diagrams.

To designate each separate element of a key diagram use is made of figure indexes. For this purpose each separate unit is assigned a hundred numbers within which similar components are numbered beginning from 1. The first two figures designate the unit number, the following figures, ordinal numbers of the given types of the elements. For example, designations R7-3, C7-21 given on the diagram should be deciphered as follows: R, C – letter designations of the diagram elements (resistors and capacitors) 7 – unit number: 3, 21, etc. – ordinal numbers of the like types of components.

Full designations of the diagram elements, their types, tolerance and other data are given in the summary Specification (Appendix 4).

.../Chapter 2

Chapter 2

TRANSMITTING SYSTEM

1. GENERAL INFORMATION

The transmitting system of the station is designed for generating radio-frequency pulses with the power of about 250 kW, of 0.5 microsecond duration and 1875 c/sec repetition frequency. The frequency range of the transmitter is from 2700 Mc/sec (11.1 cm) to 2860 Mc/sec (10.5 cm). The frequency band of the station is obtained by use of four magnetrons of the following frequency ranges:

MI-18:	2820 to 2860 Mc/sec.	(10.638 to 10.489 cm.)
MI-19:	2780 to 2820 Mc/sec.	(10.791 to 10.638 cm.)
MI-20:	2740 to 2780 Mc/sec.	(10.948 to 10.791 cm.)
MI-21:	2700 to 2740 Mc/sec.	(11.111 to 10.948 cm.)

The transmitting system consists of a driver, a modulator, a magnetron oscillator and a high-voltage rectifier (Fig.13), which are mounted on the chassis placed in the transmitter cabinet (Figs 14 and 15) located in the middle of the trailer body.

The modulator oscillator and high-voltage rectifier are housed in one modulator-oscillator unit.

The driver produces positive square pulses with an amplitude of 2700 V and of 0.5 microsecond duration to control the modulator.

The modulator is a powerful electronic switch that feeds the magnetron oscillator with a voltage of about 22 kV for 0.5 microsecond and cuts it off for 533 microsecond.

The magnetron oscillator serves to generate A.C. high-frequency pulses of about 250 kW power.

The high-voltage rectifier is designed to supply the magnetron oscillator with a voltage (of about 22 kV.)

.../2. FUNCTIONAL

2. FUNCTIONAL DIAGRAM OF TRANSMITTING SYSTEM

Fig.16 shows the transmitting system functional diagram. The negative trigger pulses of 1.5 microseconds with an amplitude of about 15 V and of 1875 c/sec repetition frequency fed out from the range unit control the operation of the driver electron relay.

The electron relay produces negative square pulses of 0.9 microseconds duration with an amplitude of 160 V which are fed to the inverter.

The inverter amplifies these voltage pulses simultaneously altering their polarity from negative to positive without changing their duration. Then they are supplied for further amplification by the first and second power amplifiers.

From the output of the second power amplifier the negative pulses are passed through the delay line to the input of the first amplifier valve with a delay of 0.5 microsecond after it has been triggered by positive pulses coming from the inverter.

From pulse transformer Tr23-2 changing the polarity of voltage pulses, positive pulses with an amplitude of 2700 V and of 0.5 microsecond duration are applied to the modulator valve grids.

Two rectifiers located in the driver supply the grid and plate circuits of the driver valves, except for the plate circuits of the second power amplifier which are fed by the rectifier situated in the modulator-oscillator unit.

Storage capacitor C25-5 placed in the modulator is charged to 22 kV by the high-voltage rectifier.

In the intervals between the voltage pulses furnished by the driver, the modulator valves are not conducting as they are cut off by negative bias, and the storage capacitor cannot discharge through them.

The positive voltage pulses coming from the driver make the modulator valves conducting for 0.5 microsecond, the storage capacitor discharges

.../through the

through the modulator valves and magnetron which generates ultra high-frequency pulses of about 250 kW power. Upon cessation of the voltage pulse action, i.e. after 0.5 microsecond, the modulator valves are cut off again by bias voltage and the magnetron stops generating oscillations until the next positive pulse arrives from the driver.

The ultra high-frequency pulse 250 kW pulse of 0.5 microsecond duration produced by the magnetron is passed to the antenna through the feeder coupled to the magnetron.

In parallel with the magnetron are connected damping diodes which suppress spurious oscillations appearing in the modulator circuit after the modulator valves have been cut off.

3. DRIVER

The driver is composed of the following elements: an electron relay, an inverter, the first and second power amplifier, two pulse transformers, a delay line and two rectifiers.

A key diagram of the driver is shown in Fig.17 (See Album).

The front panel and general view are given in Figs 18 and 19.

Electron Relay

The electron relay is the driver input stage forming the negative square voltage pulse whose shape and duration are determined by the parameters of the electron relay. Within certain limits the form and duration of the pulses are not dependent upon those of the trigger pulse.

The electron relay (Fig.20) utilizes double triode V23-1 (6N8S) and is triggered by the negative pulse with an amplitude of about 15 V coming from the range unit.

Before supplying the trigger pulse the right-hand triode of valve V23-1 is cut off by a negative bias of about -16 V applied to grid 1 of the right-hand triode from the voltage divider formed by resistors R23-7 and R23-8 which is supplied by -230 V bias rectifier. The left-hand triode of the valve is opened as its grid voltage approximates to zero.

In this case capacitor C23-2 is charged to the plate voltage value of the electron relay (to +230 V). The plate current flowing through the left-hand triode develops voltage drop across resistor R23-5, as a result the potential of the left-hand triode plate 5 is approximately equal to +120 V.

The negative trigger pulse from the range unit is applied to grid 4 of the valve left-hand triode through a differentiating circuit composed of capacitor C23-1 and resistor R23-2 with a time constant of about 0.15 microseconds. The negative pulse cuts off the left-hand triode (Fig.21,a) which causes voltage to build up across the left-hand triode plate (Fig.21, b,c). This voltage rise is applied through coupling capacitor C23-3 to grid 1 of the right-hand triode, which results in opening of the triode (Fig.21, d).

With the left-hand triode cut off, capacitor C23-3 charges through resistor R23-5 and the grid - cathode section of the right-hand triode.

The time constant of the charging circuit (C23-3, R23-5) is rather large (approximately 30 microseconds) therefore, with the left-hand triode cut off for about 0.9 microseconds the right-hand triode of the valve remains conducting; the grid voltage and plate current in it are changed inconsiderably during this time interval (Fig.21, d,e). When plate current appears in the right-hand triode, voltage drop develops across resistor R23-6 and choke L23-1, which results in reduction of potential at plate 2 by approximately 160 V (Fig.21, f). The voltage reduction is applied through coupling capacitor C23-2 to the grid of the left-hand triode, as a result the left-hand triode remains cut off though the trigger pulse is no longer applied.

The voltage reduction on the plate of the right-hand triode causes capacitor C23-2 to discharge gradually through the right-hand triode and resistor R23-2. As the capacitor discharges the voltage drop across resistor R23-2 caused by the capacitor discharge, current decreases

.../gradually in

gradually in value and the left-hand triode grid voltage increases. At the moment when the grid voltage slightly exceeds the trigger level, a small plate current appears in the left-hand triode. The voltage drop across resistor R23-5 causes the drop in the plate potential of the left-hand triode. This voltage drop is fed out through capacitor C23-3 to the grid of the right-hand triode thereby causing a decrease of its plate current and, consequently, an increase of its plate potential. The increase of voltage on the plate of the right-hand triode is applied to the grid of the left-hand triode through coupling capacitor C23-2 and causes further rise of its plate current.

Thus, at the instant when the left-hand triode grid voltage reaches the trigger level, the left-hand triode current increases in an avalanche-like manner and the right-hand triode plate current fully decreases which means the circuit comes back to the initial position. The electron relay remains in this state until the next trigger pulse arrives from the range unit.

The duration of the negative voltage pulse at the plate of the right-hand triode, i.e. the time for the circuit turn over, is determined in the main by the time constant of the capacitor (C23-2) discharge circuit.

The negative square pulse of 0.9 microseconds duration (Fig.21, f) generated by the electron relay is furnished from the plate of the right-hand triode V23-1 to the grid of the inverter valve V23-2 through isolating capacitor C23-4.

The repetition frequency of the electron relay pulse corresponds to the frequency of the trigger pulses supplied from the range unit, and is 1875 c/sec.

The plates of the electron relay are fed from the rectifier +500 V through damping resistors R23-41, R23-34 and R23-33.

The amplitude value of the negative pulse voltage produced by the electron relay is approximately equal to 160 V.

.../Placed in

Placed in the plate circuit of the right-hand triode is correcting choke L23-1 which serves to improve the pulse wave-form.

Inverter

The inverter is designed to amplify and reverse polarity of the negative pulse furnished by the electron relay. A positive pulse is formed at the inverter output which is required for removing cut-off bias in the valve of the next stage (first amplifier) which is cut off in the time interval between the pulses.

The inverter employs valve V23-2, type 6P3S, (beam tetrode) used as a triode. The valve plate circuit is supplied from the +500-volt rectifier.

If there is no negative pulse applied from the electron relay the valve grid voltage approximates zero and the current flowing through the valve is about 45 mA, the plate voltage of the valve being in the region of 105 V.

When the control grid is fed with the negative pulse the inverter valve is completely cut off and positive voltage pulse is built up on its plate, which is impressed on the control grids of the first power amplifier valve (V23-3) through isolating capacitor C23-5. During the pulse action the valve grid voltage becomes positive with the resultant grid current in the valve.

The grid current of the first power amplifier valve flows through resistor R23-10 and develops voltage drop across it equal approximately to 135 V, which keeps the voltage on the plate of valve V23-2 below 365 V during the pulse action.

Thus, the amplitude of voltage pulses on the plate of valve V23-2 is clipped by the grid current of the first power amplifier and makes up approximately 260 V.

Apart from correcting choke L23-2 the plate circuit of valve V23-2 includes resistor R23-10, which serves to improve the pulse wave-form at the inverter output.

Fig.22 shows voltage and current curves in the inverter circuits. It should be borne in mind that the curve of the inverter plate current has the form shown in this figure only in case the second power amplifier is not functioning. At normal full connection of the driver the voltage pulse wave-form on the inverter plate is slightly changed by the action of the negative voltage pulse. This pulse is supplied from the second power amplifier output to the input of the first amplifier through the delay line and to the inverter plate through coupling capacitor C23-5.

First Power Amplifier

The first power amplifier employs valve V23-3, type GI-30, (a beam dual tetrode) is designed for further amplification of the pulse furnished by the inverter.

The simplified diagram of the driver power amplifiers is shown in Fig.23.

When there is no pulse applied, both halves of the first amplifier valve are cut off by a negative voltage of -230 V applied to the control grids from the bias rectifier (valve V23-6). When the positive voltage pulse (Fig.24, a) is applied from the inverter to the control grid of valve V23-3 the valve of the first power amplifier is made conducting.

The plate load of the first power amplifier is the primary winding of pulse transformer Tr23-1. The secondary winding of the transformer is the load of the grid circuit of the second power amplifier.

The plate current flowing in the first power amplifier valve (Fig.24, b) develops voltage drop across its load, resulting in voltage pulse of negative polarity on the valve plate whose wave-form approaches the square-wave (Fig.24, c).

The secondary winding of pulse transformer Tr23-1 is connected into the grid circuit of the second power amplifier valve so that the positive voltage pulse produced in this winding is applied to the valve grids of the next stage.

.../The main

The main function of pulse transformer Tr23-1 is to convert the negative pulse into a positive one. Nevertheless, the transformer matches the output resistance of the first power amplifier with the input resistance of the second power amplifier.

The transformation ratio of transformer Tr23-1 is 2.5:1 and relationship of pulse voltages across the primary and secondary windings is 790:320 V, respectively.

The application of such a step-down transformer is necessitated by keeping, during the pulse action, a considerable grid current (about 2 A) consumed by the grid circuits of the second power amplifier.

Reduction of the pulse duration to 0.5 microsecond in the first amplifier circuits can be explained by the action of the second power amplifier and the delay line.

The plate and screen circuits of valve V23-3 are supplied by the +850 V rectifier located in the driver unit. To prevent appearance of spurious oscillations the screen circuits include grid suppressors R23-13 and R23-14, 51 ohms each, whereas the plate circuits - resistors R23-15 and R23-16, 10 ohms each (Fig.17).

Second Power Amplifier.

The second power amplifier is designed for further amplification of voltage and power of the pulse furnished by the first amplifier.

The amplifier employs two valves V23-4 and V23-5, type GI-30, connected in parallel. Thus, the second power amplifier uses a parallel combination of four tetrodes.

Resistor R23-28 serves to clip the current flowing directly from the rectifier when valves V23-3 and V23-4 are conducting.

In pulse intervals the valves of the second power amplifier are cut off by a negative voltage of -230 V fed to the control grids from the bias rectifier (valve V23-6).

The valve plates are supplied with D.C. voltage from the +4000-volt rectifier accommodated in the modulator-oscillator unit.

With the positive voltage pulse impressed on the control grids of the amplifier valves a large pulse current flows through the valves. This current is maintained due to discharge of capacitor C23-8 which is charged during the pulse intervals up to the plate voltage of the second power amplifier.

Connected into the discharge circuit of capacitor C23-8 is the primary winding of transformer Tr23-2. The winding is the plate load of the second power amplifier valves. Thus, the second power amplifier is a transformer-coupled amplifier based on a circuit with a parallel supply.

If transformer Tr23-2 were connected similarly to transformer Tr23-1 (Fig.25), large D.C. potential difference would occur between the windings of transformer Tr23-2, amounting to about 5400 V (+4000 across the primary and -1400 across the secondary).

This would demand strengthening of the insulation between windings, which would result in an increase of the transformer leakage inductance and, therefore, in a slight impairment of the pulse wave-form.

When the pulse of the plate current passes through the primary winding of transformer Tr23-2, the primary winding creates the negative pulse having an amplitude of about 3200 V.

The main function of transformer Tr23-2 is to reverse the pulse polarity.

The relationship between the number of turns in the transformer windings is 1:1, but due to losses in the transformer the voltage in the secondary winding decreases approximately to 2700 V.

The positive pulse furnished from the transformer secondary winding is applied to the grids of the modulator valves.

Connected in parallel with the primary winding of transformer Tr23-2 is a chain composed of capacitor C23-9 and resistors R23-31 and R23-30,

.../which improves

which improves the wave-form of the pulse applied to the grids of the modulator valves.

Leakage inductance of the primary winding of transformer Tr23-2 and distributed capacitance of this winding, including the wiring capacitance, form an oscillatory circuit in which spurious oscillations are shock excited at the moment of the beginning and cessation of the plate pulse current of the second power amplifier valves. The correcting chain shunts this oscillatory circuit, reduces its quality and ensures quick damping of the spurious oscillations, thus improving the wave-form of the voltage pulse at the output of transformer Tr23-2.

Delay Line

To reduce the duration of the voltage pulse produced by the electron relay from 0.9 microsecond to 0.5 microsecond use is made of a delay line made in the form of an artificial line. The delay line is connected between the output of the second power amplifier and the input of the first power amplifier (Fig.23).

The delay line acts as follows. The voltage divider formed by resistors R23-29 and R23-40 furnishes part of the pulse voltage of negative polarity to the line input. A series combination of four sections of inductor L23-3 and a parallel combination of capacitors C23-10 and C23-22, C23-11 and C23-23, C23-12 and C23-24, C23-13 and C23-25 prevent instantaneous transmission of voltage along the line. As a result the voltage pulse at the line output appears and vanishes a bit later than at the line input. The line parameters are selected so that the pulse delay time equals 0.5 microsecond.

To avoid reflection from the line end, the line is loaded by resistor R23-39 whose value approximates the line wave impedance.

The pulse of 0.9 microseconds duration generated by the electron relay is narrowed on the grid of the first power amplifier (valve V23-3). The

.../grid of

grid of this valve is supplied with the positive voltage pulse from the inverter and the negative pulse delayed for 0.5 microsecond from the second amplifier through the delay line.

The amplitude of the negative voltage pulse exceeds that of the positive pulse, therefore, the first amplifier is cut off by the negative pulse from the delay line 0.5 microsecond after it has been made conducting by the pulse furnished from the inverter. Thus, the valve is conducting during 0.5 microsecond, hence the voltage pulse duration at the anode (plate) of the first power amplifier and in the successive stages is 0.5 microsecond.

Fig.26 shows the voltage curves in various points of the power rectifier circuit (by a line of dashes - when the delay line is absent and by a continuous line - curves actually observed when the delay line is present).

The pulse from the delay line output is applied to the control grid of the first power amplifier through capacitor C23-19 isolating the valve grid from the chassis for D.C. The capacitance value of this capacitor is taken small (47 pF) to diminish its influence upon the inverter pulse form as the capacitor shunts the plate load of valve V23-2 for A.C.

Pulse Transformers

Transformers Tr23-1 and Tr23-2 are transformers of a special type intended for undistorted transmission of short pulses. To perform this operation it is necessary to ensure minimum leakage inductance in the transformer and minimum capacitance between the windings. Reduction of leakage inductance is obtained by the close arrangement of the transformer windings, whereas reduction of interwinding capacitance is achieved by placing them as far apart as possible.

The problem is solved by arranging the windings in a special manner. Leakage inductance is minimum if both windings have the same volume. Therefore, each winding of transformer Tr23-1, having transformation ratio 2.5:1, consists of two sections, the primary sections being connected in series, and the secondary sections - in parallel (Fig.27).

Used as a core material is permalloy - an alloy of iron and nickel - having high magnetic permeability.

To reduce eddy current loss, silicon is added to the alloy, the laminations are made 0.1 - 0.12 mm thick and are thoroughly insulated from each other by a film of varnish applied to one side of each lamination.

The core of transformer Tr23-2 is greater in volume than that of transformer Tr23-1 as the power transmitted by the transformer Tr23-2 reaches 50 - 55 kW during the pulse time.

Driver Rectifiers

The driver unit is provided with a plate rectifier and a bias rectifier.

The bias rectifier (Fig.28) uses valve V23-6 (kenotron, type 5C4S) in a full-wave circuit. It produces bias voltage (-230 V) to supply the first and second power rectifier valves. The bias voltage applied to the electron relay (-16 V) is taken off the voltage divider which is also fed by the same rectifier. Besides, the rectifier supplies an electron time relay incorporated in the modulator unit. In some stations the -230 V rectifier supplies relay P23-1 through series resistor R23-32.

Note: The electron time relay and relay P23-1 are described below in Section 7.

The bias rectifier filter consists of capacitor V23-14 and choke DL23-1. The primary winding circuit of transformer Tr23-3 includes fuse B23-1 located on the front panel of the unit.

The plate rectifier of the driver unit (Fig.29) utilizing two valves V23-7 and V23-8 (kenotrons, type 5C4S) and transformer Tr23-4, is represented by two independent rectifiers for +500 V, and +350 V, connected in series.

The rectifier rated for +500 V supplies the plate circuit of the inverter and electron relay. The mid-point of the transformer plate winding (i.e. minus) of the +350 V rectifier is connected to the output (plus) of the rectifier, +500 V. Thus, the total voltage of the driver second

.../rectifier equals

rectifier equals +850 V. The voltage of +850 V is used for supplying the plates of the first power amplifier and the screen grids of the first and second power amplifiers.

The primary winding circuit of transformer Tr23-4 includes fuse B23-2, located on the front panel of the unit.

The filament voltage of the driver valves is taken from transformer Tr23-5 (Fig.17) which is provided for this purpose with four secondary windings: a winding with taps 9 and 10 for heating valves V23-1, V23-2, V23-3, V23-4 and V23-5 of the driver unit; a winding with taps 5 and 6 for kenotron V23-7 and a winding with taps 7 and 8 for kenotron V23-8 of the double rectifier. The fourth winding with taps 3 and 4 is not used in the driver unit.

The mains voltage is applied to the driver unit through connector Zw23-1, whose contacts 15 and 16 supply 110 V, 427 c.p.s. to transformers Tr23-3 and Tr23-5, whereas contacts 11 and 12 - to transformer Tr23-4. Connector Zw23-1 is simultaneously used for feeding the driver rectifier voltages to an indicator, type Pp25-3, (marked VOLTAGE CHECK) located on the front panel of the transmitter unit, and to the electron time relay placed in the modulator unit.

The indicator, type Pp25-3, is supplied through contact 5 and series resistor R23-38 with a voltage of -230 V; through series resistor R23-36 and contact 9 of connector Zw23-1 with a voltage of +500 V and through resistor R23-37 and contact 7 with a voltage of +850 V. All these voltages are fed to the instrument through selector switch W25-4.

The instrument connections are made in such a way that when voltages of -230, +500 and +850 V are checked the instrument pointer must be between the red marks made on its scale.

Voltage to the electron time relay is applied through contact 13 of connector Zw23-1. In drivers of stations of earlier design the contact circuit of relay P23-1 is closed through contacts 13 and 14 of connector Zw23-1.

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.../The plate

The plate voltage of +4000 V is applied to the second power amplifier from the rectifier, +4000 V, located in the modulator-oscillator unit, through high-voltage connector Zw23-2. The pulse voltage is impressed on the grids of the modulator valves from transformer Tr23-2 through high-voltage connectors Zw23-6 and Zw23-7.

MODULATOR.

The modulator is a powerful electronic switch periodically energizing the magnetron plate circuit. The basic elements of the modulator are formed by three valves V25-1, V25-2 and V25-3 (type GMI-30) connected in parallel, storage capacitor C25-5, three damping diodes V25-4, V25-5 and V25-6 (W1-0.1/40) and charging choke L25-2.

Key diagrams of the modulator-oscillator unit are shown in Figs 30 and 30,a (See Album).

The grids of the modulator valves are furnished with the constant negative bias of -1400 V from the bias rectifier employing valve V25-8 (VU-111-D). During pulse intervals the modulator valves are cut off. The plates of the modulator valves are connected to storage capacitor C25-5 (Fig.31).

In time intervals between the positive pulses fed to the grids of the modulator valves, the storage capacitor is charged by the high-voltage rectifier to a voltage of about 22 kV. The capacitor is charged along the following circuit (Fig.31): plus of the high-voltage rectifier, current-limiting resistors R25-36, R25-35, capacitor C25-5, choke L25-2, milli-ammeter Pp25-2, minus of the rectifier (ground).

When the positive pulse is received from the driver to the grids of the modulator valve (Fig.32, a), the valves become conducting and the magnetron is connected into the charging circuit of storage capacitor C25-5, in series with the modulator valves. In this case voltage drop across the modulator valves will be comparatively small (approximately 1 - 1.5 kV) and almost entire voltage of the storage capacitor is applied

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in negative polarity to the magnetron cathode, as the anode is earthed (Fig.32, c, d). The magnetron generates oscillations of ultra-high frequency.

Due to relatively large capacitance of storage capacitor C25-5 (0.125 microF)and short discharge time (0.5 microsecond), the voltage across the capacitor during the discharge time decreases by a value not exceeding 200 V (Fig.32, b). Thus, the voltage impressed on the magnetron remains practically constant during the pulse time.

The conducting modulator valves pass besides discharge current of capacitor C25-5, the current supplied directly by the high-voltage rectifier. For limiting the value of the rectifier current flowing through conducting modulator valves, current-limiting resistors R25-35 and R25-36 are included in the circuit.

The value of these resistors is such that during the resting time storage capacitor C25-5 may practically be charged up to full rectifier voltage.

In time intervals between the pulses charging current of capacitor C25-5 flows through milliammeter L25-2. During the pulse time capacitor C25-5 discharges through the magnetron. In this case the instrument reads the magnetron average current as the electricity stored by the capacitor during the pulse intervals equals the electricity lost by the capacitor during the pulse time.

The average value of the magnetron current at normal operating conditions of the magnetron amounts to 21 - 23 mA.

Knowing average magnetron current I_{av}, pulse duration τ and pulse repetition rate T it is possible to determine the magnetron pulse current. According to equation $I_{pulse} = \frac{I_{av}\ T}{\tau}$. In this case: $\tau = 0.5$ microsecond

$T = \frac{1}{1875}$ sec. = 533 microseconds. Hence the magnetron current during the pulse will be:

$$I_{pulse} = I_{av.} \times \frac{533}{0.5} = 22 \times 10^{-3} \times 1066 = 23.5 \text{ Amp.}$$

To provide the proper pulse wave-form of high-frequency oscillations produced by the magnetron, the wave-form of the pulse produced by the

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.../modulator must

modulator must approach the square wave-form. For this purpose a number of correcting elements is placed in the modulator circuit.

To increase the steepness of the pulse trailing edge the grid circuit of the modulator valves includes choke L25-1 (2.5 mH) and in parallel with the magnetron - choke L25-2 (5 mH). Choke L25-2 serves to increase the steepness of the voltage pulse trailing edge on the magnetron cathode. The choke ensures more rapid discharge of the capacitance existing between the magnetron cathode circuits and earth (capacitor Cp see Fig.31) after the modulator valves have been cut off. By the time the modulator valves are cut off, the current in the choke amounts to rather a large value (of the order of 2.2 A). With the valves cut off this current ensures rapid discharge of the stray capacitance between the magnetron cathode and earth, its value is not diminishing with time but, on the contrary, increases until the voltage between the magnetron cathode and earth falls practically to zero.

After that the current in the choke begins decreasing whereas the voltage on the magnetron cathode starts increasing, being positive in relation to earth.

Thus, damped oscillations should develop in the circuit formed by choke L25-2 and the stray capacitance: magnetron cathode - earth (Cp). During negative half-periods of this damped A.C voltage high-frequency oscillations might be regenerated on the magnetron cathode. To damp spurious oscillations in the circuit and thereby prevent regeneration of high-frequency oscillations damping diodes V25-4, V25-5 and V25-6 (kenotrons, type B-0.1/40) are connected in parallel with the magnetron. During the positive half-wave the diodes shunt the oscillatory circuit and the spurious oscillations are quenched. Fig.33 shows voltage pulse wave-forms on the magnetron cathode for three versions of the circuit: with inductance (L25-2) without diodes, with diodes without inductance, and with diodes and inductance.

.../Choke L25-1

Choke L25-1 increases the steepness of the pulse trailing edge on the grids of the modulator valves, thus ensuring a most rapid discharge of the capacitance existing between the modulator valve grids and earth.

To check the wave-forms of voltage pulses on the grids of the modulator valves and on the magnetron cathode the right-hand part of the transmitter cabinet front panel is provided with test connectors Zw25-3 and Zw25-4. Voltages are applied to these connectors from capacitive voltage dividers formed by capacitors C25-3 - C25-2 and C25-7, and capacitance between the screw fastening the insulator of storage capacitor C25-5 and capacitor C25-5 itself. The screw is isolated from the chassis.

Test connectors Zw25-3 and Zw25-4 are connected with the capacitive voltage dividers through resistors R25-34a - R25-34b and R25-33, which serve to suppress spurious oscillations occurring in the pilot circuits.

The grid and plate circuits of the modulator valves include grid suppressors; in grid circuits they are as follows: R25-43, R25-44, R25-45 (10 ohms each); in plate circuits R25-40, R25-41, R25-42 (10 ohms each). The grid suppressors serve to damp spurious oscillations appearing sometimes in the circuit consisting of distributed stray inductances and capacitances, as well as to equalize load currents in the grid and plate circuits of all three triodes.

5. MAGNETRON OSCILLATOR

The magnetron oscillator serves to produce strong high-frequency pulses. Frequency of the generated oscillations is within the range of from 2700 to 2860 Mc/sec, the pulse power is 250 kW, and the pulse duration is 0.5 microsecond. It consists of a special oscillation valve magnetron and a permanent magnet between the poles of which the magnetron is placed.

The magnetron generates high-frequency oscillations when it is supplied with plate voltage coming from the modulator.

The high-frequency energy is passed from the magnetron to the station antenna through the feeder line.

Magnetron

The transmitter unit of the radar station employs a multi-cavity magnetron, type MI-18 (MI-19, MI-20, MI-21).

The magnetron (Fig.34) consists of the following main components: an anode block, a cathode, a high-frequency lead, heater leads and a finned body.

The anode block of the magnetron is a metal cylinder in which eight cavities are cut connected with the central one by slots. The inner surface of the anode block consists of a combination of slots and segments.

At ultra-high frequencies current flows not through the metal body of the entire anode block of the magnetron, but only through a thin surface layer. Thus, it appears as if the block cavities were made up of a thin conducting film of metal and the remaining volume of metal is an ideal dielectric for ultra-high frequencies.

Each cavity together with a slot is a resonance circuit which is coupled to the central cavity and the remaining circuits.

An output coupling loop is inserted into one of the anode circuits to transmit the ultra-high frequency energy from the magnetron to the feeder.

Due to close coupling between the resonance circuits the energy of all the block circuits is passed to the feeder through the high-frequency lead.

The central cavity incorporates a powerful oxide-coated cathode serving as an electron emitter. The heater leads of the magnetron are insulated from the body and are protected against damage by a glass cup.

To make cooling of the magnetron more effective the outer circumference of the anode block is fitted with radiating fins which stand in the way of the air flow forced by the fan.

Thus the magnetron is a cylindrical two-electrode valve with a special anode. When the magnetron is functioning it is placed in permanent magnetic field directed along the cathode axis.

.../The nature

The nature of physical process, occurring in the magnetron when high-frequency oscillations are generated, can be approximately presented as follows:

Each electron moving in space between the magnetron anode and cathode is acted on by three fields: permanent magnetic field H (directed along the cathode axis); permanent radial electric field E, (directed fron the anode to the cathode); a high-frequency electric field (set up between the anode-block segments).

The influence of electric field E upon the negative charge is characterized by the force proportional to the electric field intensity $F_E = e.E.$

The influence of the magnetic field upon the moving charge is characterized by the force proportional to the intensity of magnetic field H and charge velocity v:

$$F_H = K.v.H.$$

where K is proportionality coefficient.

The direction of force F_E acting on the negative charge in the electric field is opposite to the direction of intensity of field E. Force F_H acts on the moving charge in the direction perpendicular to velocity vector v and the magnetic intensity vector H, and therefore, changes only the direction of the charge travel, the absolute velocity value being unchanged.

The trajectories of electrons in the two-electrode cylindrical magnetron are shown in Fig.35.

When there is no magnetic field the electron travels along the straight line (trajectory A); with the magnetic field intensity less than certain value Hk, the electron trajectory differs from the straight line (trajectory B); with the magnetic field intensity exceeding value Hk called critical field intensity, the trajectory is curved so that the electron without reaching the anode comes back to the cathode (trajectory C).

.../A more

A more detailed analysis of the motion of electrons in electric and magnetic fields arranged at right angles (when the magnetic field intensity exceeds the critical intensity) shows that the electron trajectory is a cycloidal path, i.e. resembles the trajectory of a point on the rim of a wheel rolling over the surface without sliding (Fig.36).

As the electron moves away from the cathode its velocity increases and when it reaches the cathode its velocity decreases and at the cathode surface the velocity equals zero.

Thus, the motion of electrons in a magnetron with a planar cathode may be considered as a sum of two motions, uniformly-translational motion in the direction parallel to the anode surface, and rotary motion.

The velocity of translational movement of the electron, i.e. the average velocity of the electron in the direction parallel to the anode surface, is proportional to $\frac{E}{H}$.

To explain the process of maintaining sustained oscillations in the magnetron let us assume, as it is usually done when analysing the operation of self-excited generators, that at the initial moment there are high-frequency oscillations caused in the cavities by an external cause (sharp change of voltage, etc.). These oscillations whose frequency is determined by the cavity dimensions develop at the slots of the cavities, i.e. between adjacent anode segments, an alternating electric field.

The oscillatory circuits (cavities) are coupled to each other by the segments of the anode central cavity. Therefore oscillations in any pair of neighbouring circuits are shifted in phase by one half-period (Fig.37). By selecting the magnitude of relation $\frac{E}{H}$, it is possible to set such a velocity of the translational movement of electrons which are in the space between the cathode and anode, that the time required for the electron to cover the distance equal to that between the anode slots, will amount to one half-period of resonant oscillations in the anode circuits. When the

.../mentioned condition

mentioned condition is observed the electron, that left the cathode and passed by the first encountered anode slot at the instant when the maximum retardation field of high-frequency oscillations acts about the slot, will approach the next anode slot just at the moment the maximum retardation field also acts near it.

When the electron moves at the first slot in the retardation field its velocity is slightly decreased. This means that part of the electron kinetic energy is spent to increase the energy stored in the circuit, i.e. to increase the energy of radio-frequency oscillations. Due to a decrease in the kinetic energy the electron while travelling further along its trajectory completely loses its velocity, i.e. stops at some distance from the cathode without reaching its surface. Then by the action of the positive voltage applied to the magnetron anode the electron starts moving towards the anode again describing a second path of its cycloidal trajectory. When passing near the second slot of the anode in the radio-frequency retardation field the electron gives up part of its kinetic energy this time to the second anode circuit. As a result the next path of the cycloidal trajectory of the electron begins at the point located at greater distance from the cathode, etc.

Thus passing near the anode slots and each time giving part of the energy gained due to the anode voltage supply to the anode circuit the electron gradually moves away from the cathode and ultimately reaches the anode (Fig.37).

It is obvious that the electron energy given up to the oscillatory circuits favours maintenance of sustained oscillations in them. Therefore, the electrons like those considered above may be called the electrons moving in a favourable phase.

Besides these electrons, the cathode emits electrons that start moving in an unfavourable phase. Passing near the first encountered slot this

.../electron gains

electron gains additional acceleration, as a result it arrives at the cathode surface with appreciable velocity and is absorbed by the cathode. Therefore, the electrons leaving the cathode surface in the unfavourable phase gain acceleration in the radio-frequency field once. The electron transit time in the space between the cathode and the anode is much shorter than that of the electron that left the cathode in the favourable phase.

Thus, the so-called "sorting" process takes place in the magnetron as a result of which at any moment the inter-electrode space of the magnetron contains much more electrons moving in the favourable phase than those moving in the unfavourable phase.

A more detailed analysis shows that the radio-frequency field component perpendicular to the anode surface also furthers bunching of electrons into clouds around those moving in the most favourable phase.

Thus the density of electrons moving in the space charge is not uniform. The space charge regions with the most heavy density of electrons take the form of a spoked wheel which rotates about the cathode (Fig.38). The space charge spokes rotate in synchronism with oscillations of the anode block electromagnetic field. Each spoke of the space charge passing the anode slots encounters maximum retardation radio-frequency field and gives up part of the energy of its electrons to the oscillatory circuits thus maintaining sustained oscillations in the circuits.

The magnetron, type MI-18 (MI-19, MI-20, MI-21), employed in station SON-9 operates under pulsed conditions. The magnetron anode is earthed. The cathode is fed with negative voltage pulses. The frequency of the magnetron generated oscillations is determined in the main by dimensions of the cavities but in narrow limits it may be varied depending upon the magnetron mode of operation.

For optimum mode of operation the magnetron cathode should be furnished with pulses of 20 - 22 kV, whereas the magnetic-field intensity should amount to 1900 oersteds. In these conditions the pulse current through

the magnetron is 23.5 A.

When the ratio of the period of pulse repetition to the duration of the pulse (T) is 1066, then the average value of the current through the magnetron is 22mA.

Permanent Magnets

To create a magnetic field required for the magnetron operation use is made of permanent magnets fabricated from magnico alloy.

The magnets are comprised of two horn-like poles 2 (Fig.39) between which magnetron 4 is placed. Both poles are secured on steel plate 5 having low magnetic resistance.

The poles are placed opposite to each other and the gap between them can be varied with the help of a worm gear when rotating knob 1 situated on the magnet plate.

The plate with the magnets is attached to base 9 which in its turn is secured to the antenna pedestal foundation. Fixed to the same base by three thumb-screws is plate 6 which mounts the magnetron. The magnetron is located in the gap between the poles in such a way that the lines of force of the magnetic field built up by the magnets are in parallel with the magnetron cathode.

The average value of the magnetic field intensity must make up 1900 oersteds, but the value may vary for various magnetrons.

The required value of the magnetic field intensity is provided during tuning by rotating the gap control knob according to instruments Pp25-2 (MAGNETRON CURRENT) and Pp25-1 (HIGH VOLTAGE) situated on the front panel of the modulator-oscillator unit.

6. RECTIFIERS

The modulator-oscillator unit accommodates three rectifiers as follows: a rectifier +4000 V, a rectifier -1400 V and a high-voltage rectifier for 22 kV.

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.../The rectifier,

The rectifier, +4000 V, is a plate voltage supply of the driver second power amplifier valves. The rectifier is based on a full-wave circuit using valves V25-9 and V25-10 (kenotrons, type VU-111-D).

The rectifier circuit includes plate transformer Tr25-4, heater transformer Tr25-5 (Fig.40) and filter capacitor C25-8. To protect the rectifier from overloads, overload relay R25-4 is placed in its negative circuit. This circuit also includes undervoltage relay P25-8 which will be dealt with in section 7 of the present Chapter.

The value of the rectifier voltage is checked by instrument Pp25-3 marked VOLTAGE CHECK (with switch W25-4 in position +4000) located on the front panel of the modulator-oscillator unit.

When the rectifier voltage is normal the pointer of instrument Pp25-3 should come to set between two red marks on the instrument scale.

Placed in the circuit of instrument Pp25-3 are series resistors R25-48 - R25-53 and potentiometer R25-30, which serves to set the instrument pointer in the middle between the red marks at the rectifier rated voltage of +4000 V.

The rectifier, -1400 V, produces negative bias voltage applied to the grids of the modulator valves. The bias rectifier is based on a half-wave circuit using valve V25-8, type VU-111-D (Fig.41).

The rectifier circuit includes plate transformer Tr25-9 and heater transformer Tr25-10. Capacitors C25-1 and C25-6 are used as a filter.

From the mid-point of the divider formed by resistors R25-37 and R25-38, the voltage of -820 V is applied through resistor R25-39 and connector Zw25-8 to the keep-alive electrode of the antenna change-over switch T.R. cell. Connected in series with resistors R25-37 and R25-38 is the coil winding of undervoltage relay P25-3, which operates to close its contacts in the interlocking circuit of magnetic starter P25-1 only after the voltage at the bias rectifier output has reached a value of about -1400 V (See Section 7 of the present Chapter).

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.../The rectifier

The rectifier voltage value is checked by instrument Pp25-3 (VOLTAGE CHECK) with switch W25-4 placed in position -1400.

When the rectifier voltage is normal the pointer of instrument Pp25-3 should come to set between the two red marks.

Placed in the circuit of the instrument are resistors R25-46, R25-58 and potentiometer R25-29 which serves to set the instrument pointer between the red marks.

The high-voltage rectifier, 22 kV, is used to place charge on storage capacitor C25-5 which stores the energy to supply the magnetron oscillator.

The high-voltage rectifier employs a voltage doubling circuit (Fig.42) and contains the elements as follows:

a transformer unit (high-voltage plate transformer Tr25-6 and heater transformer Tr25-8) with two kenotrons, type W1-0.1/40 (V25-11, V25-12);

capacitors C25-9 and C25-10;

potential regulator Tr25-7 (in stations of earlier design an auto-transformer or a voltage regulator is used) for continuous variation of voltage across the primary winding of high-voltage transformer Tr25-6.

The potential regulator is provided with one primary and one secondary winding. The primary winding is arranged on the rotor of the potential regulator and the secondary winding - on the stator. The rotor can turn with regard to the stator, which results in changing the coupling of the stator and rotor windings. This in turn causes the change in voltage taken from the secondary winding of the potential regulator.

The value of voltage applied to the primary winding of high-voltage transformer Tr25-6 and consequently the value of the rectifier output voltage is adjusted by means of potential regulator Tr25-7 whose control knob DECREASE - INCREASE is situated on the front panel of the modulator-oscillator unit.

The rectified voltage is taken off capacitors C25-9 and C25-10. The negative pole of the rectifier is earthed through relay P25-5 which protects from overloads.

The rectifier voltage doubling circuit consists of a series combination of two half-wave rectifiers, both rectifiers using one secondary winding of the plate transformer.

One of the half-wave rectifiers is based on the secondary winding of transformer Tr25-6, valve V25-11 and capacitor C25-9. The positive terminal of this rectifier is in point a, the negative terminal is in point b. The second rectifier is based on the same secondary winding of transformer Tr25-6, valve V25-12 and capacitor C25-10. The positive terminal of the second rectifier is in point b, while the negative one in point c.

Thus, the total voltage of both rectifiers, i.e. double voltage, is obtained between points a and b. This circuit functions as follows:

Suppose, that at a certain instant the voltage polarity across the secondary winding of transformer Tr25-6 is such, that the plate of valve V25-11 is fed with the positive voltage. By the action of this voltage, the current flowing through valve V25-11 charges capacitor C25-9 to a voltage approximating the voltage of the secondary winding of transformer Tr25-6. During the next half-cycle, when the negative voltage is applied, capacitor C25-10 charges through valve V25-12. This capacitor will charge to a voltage approximating to that of the secondary winding of transformer Tr25-6. During the period when neither of the capacitors charges both of them connected in series are discharging to the load which is under double voltage as compared with the voltage across the secondary winding of transformer Tr25-6.

The high-voltage rectifier voltage is checked by instrument Pp25-1 (HIGH VOLTAGE) connected in series with a chain of series resistors R25-1 - R25-25 making up approximately 15 megohms in all. The chain of series resistors is supplied with a half of the rectified voltage taken off capacitor C25-10. The scale of instrument Pp25-1 is graduated to measure full voltage of the high-voltage rectifier.

To protect the operating personnel against possible shocks by high voltage provision is made in the transmitting system for door interlocks W25-5 - W25-10, isolating the high-voltage rectifiers when the interlocking circuit is disconnected.

To protect the transmitting system elements against excess currents provision is made for a definite sequence of connection of separate elements, their maximum protection and emergency switching.

7. CONTROL, INTERLOCKING AND SIGNALLING CIRCUITS OPERATION

Operation of the Control Interlocking and signalling circuits.

The control, interlocking and signalling circuit of the transmitting system are shown in key diagrams of the driver and modulator-oscillator as well as on diagrams of control, interlocking and signalling circuits presented in Figs 43 and 43a (See Album). In Fig.43 a (see Album) are shown the control, interlocking and signalling circuits of the sets of earlier design.

From contact block P113-1 of the control panel the mains voltage of 220 V, 50 c.p.s. is applied to block P125-2 of the transmitting system. The mains voltage of 110 V, 427 c.p.s. is fed to contact block P125-1 from blocks P113-5 and P113-6.

With switch W25-1 disconnected all the circuits of the transmitting system are de-energized. When the switch is on the mains voltage of 220 V, 50 c.p.s. is applied through its contacts 5-6, 7-8 and 9-10 to transformers Tr25-1 and Tr25-2 for heating the modulator valves and damping diodes, to dial lighting lamps Z25-20, Z25-21 and Z25-22, electric motor M25-1 of the fan cooling the magnetron and modulator valves as well as to connector Zw25-10 for supplying the cooling fan motor in the transmitter cabinet.

Simultaneously, the mains voltage of 110 V, 427 c.p.s. is applied through contact 1-2 and 3-4 of switch W25-1 to transformers Tr25-10

.../and Tr25-5

and Tr25-5 for heating the kenotron of the -1400 V rectifier and valves of the +4000 V rectifier to transformers Tr25-8 and Tr25-3 for heating the high-voltage rectifier valves and magnetron respectively, to transformer Tr25-11 for heating the electron time relay valve, to pilot lamp N25-13 (MAGNETRON HEATING) and through contacts 15 and 16 of connector Zw25-1 to transformers Tr23-5 and Tr23-3 for heating the driver valves and -230 V rectifier, respectively.

The bias rectifier voltage (-230 V) is applied to valve V25-23 of the electron time relay. In 45 seconds, the plate current of valve V25-23 causes individual point relay P25-6 to close its working contacts.

Thus, with switch W25-1 on, voltage is applied to heater transformers of all valves of the transmitting system, to the fan motors, the bias rectifier transformer, and the electron time relay.

In stations of earlier design use is made of electromechanical relay P25-6 which is fed by 220 V, 50 c.p.s. A.C. mains.

The electron and electromechanical time relays are described below.

When the time relay operates, white pilot lamp N25-14 (TIME RELAY) comes on indicating that voltage may be applied to the modulator valve bias rectifier and to transformer Tr23-4 in the driver unit. These voltages are switched on by button W25-2 ON, BIAS, SCREEN.

Pressing button W25-2 closes the supply circuit of magnetic starter P25-1, but the latter operates only in case the contacts of door interlocks W25-5, W25-6, W25-7, W25-8, W25-9, W25-10 are closed (in stations of earlier design including the contacts of relay P23-1 located in the driver unit).

When magnetic starter P25-1 operates, green pilot lamp N25-15 (BIAS and SCREEN) comes on, the mains voltage of 110 V, 427 c.p.s. is applied to plate transformer Tr25-9 of the bias rectifier -1400 V and through contacts 11 and 12 of connector Zw25-1 to transformer Tr23-4 accommodated in the driver unit; the mains voltage of 220 V, 50 c.p.s. is applied to the electromagnet coil

.../winding of

winding of relay P25-7 which operates to open the discharge circuit of capacitors C25-9, C25-10 and C25-5.

When the modulator valve bias rectifier, -1400 V, is on, its output voltage causes relay P25-3 to operate. The relay contacts close the interlocking circuit of magnetic starter P25-1. After the starter and the relay have operated, button W25-2 ON BIAS AND SCREEN may be released, since the coil winding of the starter electromagnet is closed through the starter interlocks "A" and "B", normally closed contacts of overload relay P25-4 (as well as contacts of overload relay P25-9 in stations of earlier design), contacts of relay P25-3 and button W25-2.

Pressing any of buttons W25-3 (ON, HIGH VOLTAGE) located on the front panel of the modulator-oscillator unit or button W4-5 situated on the front panel of the range mechanism unit, closes the supply circuit of the electromagnet coil winding of starter P25-2 and causes the latter to operate. When the magnetic starter operates red pilot lamp N25-16 (HIGH VOLTAGE) comes on and the mains voltage 110 V, 427 c.p.s. is applied to transformer Tr25-4 of the rectifier (+4000 V), potential regulator Tr25-7 and through the latter to high-voltage plate transformer Tr25-6.

When the rectifier (+4000 V) is on, its load current causes undervoltage relay P25-8 to close the interlocking circuit of magnetic starter P25-2 with its contacts.

After the starter and undervoltage relay have operated, the high-voltage button may be released since the supply circuit of the starter electromagnet coil is closed through the starter interlocks "A" and "B", contacts of undervoltage relay P25-8 and normally closed contacts of overload relay P25-5 (as well as the contacts of overload relay P25-8 in stations of earlier design).

<u>Note</u>: Stations of earlier design are not provided with undervoltage relay P25-8. The same reference number stands for an overload

.../relay which

relay which is connected into the primary circuit of transformer Tr25-4 of the +4000 V rectifier.

The interlocking circuit of magnetic starter P25-2 is closed by contacts of relays P25-5 and P25-8. Opening of contacts of either relay causes breaking of the supply circuit of the electromagnet coil winding of starter P25-2 whose main contacts disconnect the supply of the high-voltage rectifier potential regulator Tr25-7 and transformer Tr25-4 of the +4000 V rectifier. The red pilot lamp N25-16 (HIGH VOLTAGE) goes out.

Thus, with contacts of relays P25-5 and P25-8 opened, the high-voltage rectifier voltage and the driver output power amplifier plate supply are off. The same will result from the operation of overload relay P25-4, from opening of contacts of relay P25-3 and of door interlocks W25-5, W25-6, W25-7, W25-8, W25-9 and W25-10.

In stations of earlier design voltages from the high-voltage rectifier and +4000 V rectifier will be switched off during operation of overload relay P25-9 and opening of contacts of relay P23-1 located in the driver unit.

When contacts of relays P25-3 and P25-4 or (in the sets of earlier design, P25-9 and P23-1) or contacts of door interlocks W25-5 - W25-10 are open, only magnetic starter P25-1 is disconnected, because the contacts of the above relays and door interlocks are placed in the supply circuit of the electromagnet coil winding.

In this case the main contacts of magnetic starter P25-1 disconnect the supply of transformer Tr25-9, transformer Tr23-4 in the driver unit, the electromagnet coil windings of relay P25-7 and as a result green pilot lamp N25-15 (BIAS AND SCREEN) goes out.

Thus, opening of contacts of any relay (P25-4 and P25-3 or in the sets of earlier design also the relays P25-9 and P23-1) or one of the door interlocks results in disconnection of magnetic starters P25-1 and P25-2 and consequently in disconnection of all the rectifiers of the transmitting system, except for the bias rectifier, -230 V, located in the driver unit.

.../When the

When the electromagnet coil windings of relay P25-7 are de-energized its operating contacts, through which capacitors C25-9, C25-10 and C25-5 are charged, close.

Potential regulator Tr25-7 whose voltage is fed to the primary winding of plate transformer Tr25-6 of the high-voltage rectifier is controlled by the knob situated on the front panel of the modulator-oscillator unit.

When turning the potential regulator knob clockwise the voltage applied from the autotransformer to the primary winding of plate transformer Tr25-6 increases, therefore, the rectified voltage rises. When turning the potential regulator knob counter-clockwise the voltage from the high-voltage rectifier decreases. To limit the turning angle of the potential-regulator rotor mechanical stops are arranged on the rotor textylite gear in two extreme positions of the potential regulator.

Time Relay

The time relay serves to close one of the branches of the control, interlocking and signalling circuit of the transmitting system with a time delay of 45 sec. The presence of the time relay makes it possible to warm up the cathode of all valves in the transmitting system before switching on the plate voltages.

The transmitter unit employs an electron time relay based on valve V25-23 (6N8S). In sets of earlier design there is used an electromechanical time relay P23-1.

Electron Time Relay

All elements of the electron time relay are mounted on a plastic board with a metal case. The general view of the electron time relay is shown in Fig.44, a, and the key diagram - in Fig.44, b.

The electron time relay is supplied by the driver bias rectifier, -230 V. Heater transformer Tr25-11 is fed with a voltage of 110 V,427 c.p.s. After switch W25-1 has been on, 110 V, 427 c.p.s. are applied to transformers

.../Tr25-11 of

Tr25-11 of the electron time relay and Tr23-3 of the bias rectifier, -230 V, located in the driver unit.

By the action of the rectifier output voltage a small plate current flows through valve V25-23 of the electron time relay. The current circuit is closed through the electromagnet coil winding of individual point relay P25-6, valve V25-23 and resistor R25-60. A voltage drop of definite polarity is developed across resistor R25-60 (Fig.44, b). Capacitor C25-19 is not able to charge instantly and this voltage will appear to be impressed between the cathode and the grid of the valve, minus on the grid. This results in clipping the current flowing through valve V25-23 of the electron time relay, and consequently through the electromagnet winding of individual point relay P25-6.

This current is initially smaller than the operating current of the individual point relay P25-6. As charge is placed on capacitor C25-19 (through resistors R25-61, R25-62 and R25-63) the negative voltage between the cathode and control grid of valve V25-19 decreases, while the current flowing through the valve and consequently through the coil winding of the individual point relay electromagnet increases. At the instant when the current flowing through the coil winding of the individual point relay electromagnet becomes equal to the operating current of the relay, the latter will operate to close its normally opened contacts in the supply circuit of magnetic starter P25-1.

The value of the time constant for the charging circuit of capacitor C25-19 and resistor R25-60 is selected in such a way that the time relay operates 45 sec. after switch W25-1 has been on.

When switch W25-1 is off the operating contacts of individual point relay P25-6 come back to the initial position.

The circuit of the electron time relay enables to increase the time delay of the relay operation. To extend it from 45 sec. to 2 min. resistor R25-63 should be removed from the circuit.

Electromechanical Relay

The general view of the electromechanical time relay is shown in Fig.44, c.

The circuits of the electromagnet and motor of the time relay are supplied with 220 V, 50 c.p.s. A.C.

When current flows through the coil of electromagnet 1 its core is pulled into the coil and turns the upper lever shaft coupled to it. In this case sprocket 10 of the upper lever comes in mesh with sprocket 4 of the reduction gear. Simultaneously with switching on the electromagnet motor 2 whose winding is in parallel with the coil of the electromagnet starts operating. The motor rotation is imparted through the reduction gear and two sprockets 4 and 10 to lever 8 which, while turning about shaft 14, reaches the bent lug of dial 5 and on further rotation carries the dial along with it. A stop secured on the dial disc presses latch 11 which releases lower lever 7. The lower lever acted on by compressed spring 9 moves down thus closing contacts 12 of the external circuit and opening contacts 13 placed in the supply circuit of the electric motor winding.

With the electromagnet voltage supply switch off the entire system is returned to the initial position by the action of the springs.

The relay is set at the required operation time delay by increasing or decreasing the length lever 8 travels until it engages the bent lug of the dial.

To set the relay at the required operation time delay it is necessary to pull the spring so that its bent end slips out of the slot in the dial disc. Then the disc should be turned to match the spring bent end with the dial slot against which the required time delay is marked.

Chapter 3

ANTENNA-FEEDER SYSTEM

1. GENERAL

The antenna-feeder system of the station is designed for conveying the electromagnetic energy produced by the magnetron, radiating it in a narrow beam into space as well as for picking up returned signals (echoes) and for passing them to the input of the receiving system.

The antenna-feeder system ensures unlimited scanning of space in azimuth and in sector and from -0-50 to +14-50 in elevation.

The antenna-feeder system is hermetically sealed. When the station is operating the dried air forced under a low pressure by the automatic air dryer (dehydrator) flows through the antenna-feeder system. This air enables the equipment to operate in any weather and causes the feeder line to pass the required power of electromagnetic energy with the minimum attenuation in the feeder.

The antenna-feeder system provides for:

- channelling of electromagnetic energy during transmission or reception within the band of operating waves of the station: 10.5 to 11.1 cm;

- transmission of peak power up to 250 kW during the pulse at travelling wave ratio not less than 0.65;

- forming the radiation pattern. Width 0-83, determined as an angle between the directions in which the radiation power equals one half of the power radiated in the direction of maximum radiation power.

2. BLOCK-DIAGRAM OF ANTENNA-FEEDER SYSTEM

The antenna-feeder system, a block-diagram of which is shown in Fig.45, consists of the following basic parts:

antenna 1 which includes antenna head 11 and parabolic reflector 12;

radio-frequency coaxial feeder 2 made of separate sections coupled with the help of fixed and rotating joints 7, 9, 10;

antenna change-over switch 3, which includes the transmitter T-junction 6 and T.R. cell 4.

The antenna is designed to radiate electromagnetic energy in a narrow beam into space as well as to pick up the signals returned from the targets within the range of this beam.

A single antenna is used for reception and transmission.

The antenna head is arranged in front of the parabolic reflector in such a manner that its radiation centre is in the focal plane of the reflector.

To create cone scanning employed during automatic tracking of the target, the radiation pattern axis is slightly tilted in relation to the geometrical axis of the parabolic reflector and traces of cone surface during the antenna head rotation.

The radio-frequency coaxial feeder is designed to convey electromagnetic energy with minimum loss from the transmitter to the antenna and from the antenna to the receiver.

Two rotating joints - azimuth joint 7 and elevation joint 9 called slow rotating joints are similar in design. They provide passing of electromagnetic energy through the feeder during rotation of the antenna in azimuth and elevation.

The third rotating joint 10 called a fast rotating joint slightly differs in design from the above two. It provides transmission of energy when the antenna head rotates at a speed of 1440 r.p.m. which is required for cone scanning of the beam.

The antenna change-over switch is designed to protect the receiver from damage by the transmitter powerful pulse.

The antenna change-over switch consists of T.R. cell 4 with a spark gap and transmitter T-junction 6 which is represented by a T-connection of the coaxial feeder, which connects the feeder with the magnetron and T.R. cell.

During the transmitter operation T.R cell 4 keeps the transmitter powerful pulses out of the receiver thereby protecting the receiver from damage.

In the transmitter resting time the T.R. cell performs the function of the input circuit that couples the antenna to the receiver.

3. BASIC NOTES ON THEORY OF ULTRA-SHORT WAVE TRANSMISSION LINES

In ultra-short wave transmission lines energy propagates along the line in the form of voltage and current waves.

Energy propagates along the line with the final velocity. During one oscillation cycle energy moves along the line to cover the distance equal to the wave length.

In case energy moves along an infinite line the voltage and current waves are in phase along its entire length, therefore, the relation of voltage to current in any point of the line remains constant and equal to the line characteristic impedance. The characteristic impedance depends upon the form and sizes of the line cross-section; the coaxial line characteristic impedance is determined by the formula

$$p = 138 \lg \frac{D}{d},$$

where D is the internal diameter of the external tube,

d is the external diameter of the internal tube.

The radio-frequency feeder used in the station is a coaxial line with dimensions: D = 20 mm, d = 9 mm; its characteristic impedance is

$$p = 138 \lg \frac{20}{9} = 48 \text{ ohms}.$$

In the real finite line loaded by resistance equal to the line characteristic impedance the same wave propagation conditions as in the infinite line occur.

If the line is loaded to a resistance unequal to the characteristic impedance the energy is partially absorbed by the load resistance and is

.../partially reflected

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partially reflected from the load back into the line. In this case two waves, i.e. voltage and current waves move along the line: one towards the load, the other from the load, the first wave exceeding the second in amplitude.

As a result of addition of these two waves the voltage amplitude value periodically varies along the line.

Such a mode of operation is characterized by travelling wave ratio, expressed as a relation of the minimum amplitude value to maximum amplitude value. The energy absorbed by the load will be greater with a higher travelling wave ratio.

The radio-frequency feeder of the station is a finite line loaded by the antenna input resistance which is approximately equal to the feeder characteristic impedance.

The antenna input resistance varies depending upon the frequency but the travelling wave ratio within the band of operating waves (10.5 to 11.1 cm.) in the antenna-feeder system is not less than 0.65.

In an open or short circuited finite line without loss (or with small loss) complete reflection takes place (Fig.46). In this case the amplitude of the voltage wave travelling from the generator to the load is equal to the amplitude of the wave travelling back over the line towards the generator. Therefore, their addition produces voltage and current standing waves in the line.

This mode of operation is characterized by sine variation of voltage amplitude value and cosine variation of current amplitude value along the line.

At the end of the short-circuited line the voltage equals zero, the current is maximum; at a distance of $\frac{\lambda}{4}$ from the end of the line the voltage is maximum and the current equals zero. Consequently, the input resistance of the quarter-wave short-circuited line which equals the voltage-to-current ratio is infinitely large.

.../It follows

It follows from this that the quarter-wave short-circuited line, connected to the generator, is equivalent to an insulator as regards its effect on the fundamental wave length, because the line input resistance equals infinity. This property of the quarter-wave short-circuited lines is the basis of the action of T-shaped insulators of the antenna feeder system.

At the end of the quarter-wave open line the current equals zero while the voltage is maximum; at a distance of $\frac{\lambda}{4}$ from the line end the voltage equals zero and the current is maximum. Consequently, the resistance at the input of the quarter-wave open line equals zero.

The quarter-wave open line, connected to the generator is equivalent by its action on the generator on the fundamental wave length to a short-circuit since the line input resistance equals zero.

This characteristic of the open quarter-wave line is used to produce a short-circuit between the conductors in rotating joints of the antenna-feeder system where difficulty is experienced in establishing a direct contact between the conductors.

4. RADIO-FREQUENCY COAXIAL FEEDER, ITS ATTACHMENT AND DESIGN

The radio-frequency feeder serves to pass powerful electromagnetic waves from the magnetron to the antenna and the signals picked up by the antenna to the receiver.

The design and attachment of the radio-frequency feeder is shown in Fig.47.

Branched off magnetron 14 is sleeve 11 connected to T-junction 12 of a transmitter coupler to which feeder section 1 is attached. The feeder runs inside the transmitter.

In the centre of the bottom part of the antenna pedestal foundation the feeder has azimuth slow rotating joint 2. From the rotating joint the

.../feeder runs

feeder runs through the hollow shaft of the antenna pedestal and at the right angle goes to elevation slow rotating joint 5.

Fast rotating joint 7 is located after tilted feeder 6.

Movable part 9 of the fast rotating joint is placed inside the frame of reference voltage generator 8. Further the feeder runs through the generator hollow shaft to antenna head 10, the generator motor and the antenna head being on a common shaft and are driven by one electric motor.

Each section of the radio-frequency feeder is made of two brass tubes, one tube being placed inside the other (coaxial line).

The current-conducting parts of the coaxial line are the inner surface of the outer tube (20 mm in diameter) and the outer surface of the inner tube (9 mm in diameter). These dimensions are optimum and ensure passing of the required power at minimum energy losses in the feeder.

The electromagnetic energy conveyed by the coaxial line is enclosed in the space between the inner and outer conductors of the line, therefore no radiation loss can take place.

The inner conductor of the line is fixed in the middle with the aid of quarter-wave short-circuited coaxial line sections.

The input impedance of a short-circuited section of a coaxial line is infinity if the length of the section equals $\frac{\lambda_o}{4}$ of the fundamental wavelength λ_o. If such a section is connected in parallel to the line, it will not act as a shunt for the fundamental wavelength, i.e. it will act as a good insulator.

If the magnetron wavelength is slightly altered, the input impedance of the quarter-wave insulator will decrease, the quarter-wave insulator will shunt the transmission line, and part of the energy will be reflected from the junction.

In order to obtain a stabilized operation of the magnetron, and full transmission of energy along the line, the travelling wave ratio in the line should be not less than 0.65 for the whole range of the operating frequencies of the set (10.5 - 11.1 cm.). SECRET

As the shunting effect of the insulators appears at the extreme wavelengths of the operating frequency range of the set, in the transmission line, together with the quarter-wave insulator, use is made of a half-wave transformer formed by a section of the internal conductor which has an increased diameter (Fig.48).

The half-wave transformer serves to compensate for the reflection introduced into the line by the quarter-wave insulator at the wavelengths which differ from the fundamental.

The input impedance of the half-wave transformer equals the load impedance connected to its output. That is why for the fundamental frequency the half-wave transformer has no influence upon the energy transmission along the line.

Therefore, for the fundamental wavelength neither the insulator, nor the transformer introduce any reflections into the line.

If the feeder operates on a wave length below the fundamental one ($\lambda < \lambda_0$) the insulator inserts reflection in the line as its input impedance is not infinitely large. In this case the insulation is a capacitive load connected to the feeder.

In this case the half-wave transformer inserts reflection in the line as well. Its action is equivalent to that of an inductive load and with the half-wave transformer acting on the feeder line, their action is being compensated mutually and partially.

Similarly compensated are reflections inserted in the line by the insulator and transformer on wave lengths above the fundamental one ($\lambda > \lambda_0$). In this case the insulator is equivalent to the inductive load, while the transformer in the first approximation is equivalent to the capacitive load.

When the diameter of the transformer inner conductor is properly selected reflections in the line (mismatch) caused by the quarter-wave

.../insulator and

insulator and half-wave transformer may be mutually compensated for within the entire operating wave band of the station.

Besides T-shaped insulators, bend-type insulators (Fig.49) are used in the feeder bends of the antenna-feeder system. This insulator consists of a short-circuited stub (quarter-wave insulator) 2 and quarter-wave transformer 4.

The quarter-wave transformer which is essentially a line section with a decreased diameter of the inner conductor, affects the operation of the feeder on the fundamental wave (inserts reflections). To compensate for this affect the length of the short-circuited stub is made smaller than $\frac{\lambda_o}{4}$. Such design of the angle provides compensation of reflections throughout the entire operating wave band of the station.

To rotate the antenna in azimuth and elevation and the antenna head without disturbing electrical coupling in the feeder provision is made for two slow and one fast rotating joint.

The design of the elevation slow rotating joint is shown in Fig.50. The inner races of ball bearings 1 and 2 are connected with the outer conductor of the right-hand part of the feeder by means of nuts 5; the outer races placed in body 14 are attached to the outer conductor of the left-hand part of the feeder by means of screws 3. The outer conductors are centred by ball bearings 1 and 2, while the inner conductors - by pin 6.

The azimuth slow-rotating joint is similar in design to the elevation rotating joint and is shown in Fig.51.

Such design of the rotating joints makes possible rotation of one feeder part in relation to the other without disturbing their centring. In this case no longitudinal displacement of one part with regard to the other is possible.

To provide hermetic sealing the slow-rotating joints are furnished with rubber washers 8 and packing collars 7.

.../The design

The design of the fast rotating joint is illustrated in Fig.52. Feeder rotating joint 1, located in the inner compartment of the reference voltage generator shaft, rotates together with the shaft. The feeder fixed section 9 is rigidly coupled to the generator frame by means of screws 4 and flange 3.

Hermetic sealing of the fast rotating joint is provided by rubber washers 6, 7 and packing collar 5.

The inner and outer conductors of the rotating joint and fixed section of the feeder overlap each other with a small constant clearance. As a result the feeders are connected by quarter-wave stubs AB and BC, DE and FE (Fig.52).

Stub AB is a short-circuited line. Its input resistance, i.e. resistance in point B, equals infinity while in point A - zero.

Stub BC is a quarter-wave line opened at the end (in point B); its input resistance in point C equals zero.

Stub DE consists of quarter-wave short-circuited line DF and quarter-wave open line FE; its input resistance in point E equals zero. Zero resistances in points C and E ensure reliable transmission of energy between the rotating joint and fixed section of the feeder.

The broad band of the rotating joints is provided by selecting clearances between the current-carrying surfaces of the quarter-wave lines opened and closed at the end.

An electric circuit of the rotating joints is shown in Fig.54.

The radio-frequency feeder sections are connected to each other by means of connectors whose design is illustrated in Fig.55.

The end faces of the outer tubes are slightly bevelled so that a reliable contact is obtained when they are connected. Rubber washers 5 placed between the collars ensure hermetic sealing. The inner conductors of the feeder are tightly coupled to each other by means of plug connectors.

.../To prevent

To prevent oxidation of contact surfaces in places of fixed connectors the current-carrying surfaces of the feeder conductors are covered with a film of gold at the ends of each section.

5. ANTENNA CHANGE-OVER SWITCH

The antenna change-over switch consists of T-junction 2 and T.R cell 1 (Fig.55).

The T-junction (Fig.56) is an intermediate link connecting the magnetron and the T.R. cell to the radio-frequency feeder.

The magnetron oscillator is connected with arm 3 of the T-junction with the aid of sleeve 4 with a ring nut 11 screwed on over the threaded part of the magnetron.

Internal conductor 12 of the coaxial output of the magnetron is connected with the transmission line with the aid of spring contact 5.

Connection between the external conductors of the high frequency magnetron output 8 and T-junction 9 is made with the aid of contact 4 of the quarter-wave line 6 and 7, which acts in the same way as the quarter-wave sections of the rotating joints. Arm 2 of the T-junction is connected to the T.R. cell by coupling loop 10, arm 1 to the transmission line leading to the antenna.

The T-junction has an attenuator 13, through which part of the energy, required for the operation of the automatic frequency control (AFC), is branched off. The attenuator is shaped like a wave-guide section the length and diameter of which is chosen to ensure that the high frequency energy of the transmitter pulse is sufficiently attenuated before reaching the mixer of the AFC.

The dimensions of arm 3 and of the sleeve (cup) 4 are chosen in such a way that the input impedance from the side of the T-junction, with the magnetron connected, equals infinity.

.../There are

There are therefore no reflections within the T-junction, and the pulse enters the T.R. cell without attenuation. The T.R. cell is tuned to the magnetron frequency with the aid of bolts 4 (Fig.57), and therefore to the frequency of the pulses reflected from the target.

Inside the T.R. cell is located T-R switch (short-circuiting valve) 2 containing a special gas mixture at low pressure. Two copper discs fused into the switch (valve) protrude outside the switch in the shape of two parallel rings. The switch envelope is made of glass with small dielectric loss at ultra-high frequencies.

The copper discs (inside the valve) carry hollow discharge cones, whose peaks are separated by a small gap. Inside one of the cones is located keep-alive electrode 11. This electrode is supplied through a damping resistor by the modulator bias rectifier with a voltage of about -820 V with respect to the earthed cones of the discharger.

As a result a glow discharge of 100 to 200 microA is continuously maintained between one of the cones and the keep-alive electrode. Due to the glow discharge there is always a certain quantity of ionized gas molecules near this cone. The ionized gas between the discharger cones facilitates the break down of the spark gap when the magnetron produces oscillations.

Outer detachable half-rings 5 of the T.R. cell resonator fitted on copper discs 10 of the discharge valve form a cavity circuit together with the valve.

The T.R. cell cavity circuit is coupled to the crystal mixer by means of coupling loop 12, while to the T-junction by coupling loop 13.

The degree of coupling of the cavity resonator with the mixer or T-junction depends upon the loop area and its orientation in relation to the resonator axis.

During reception a variable electromagnetic field is built up in the resonator cavity (cavity circuit) tuned to the magnetron frequency and

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.../therefore. to

therefore, to the carrier frequency of the echo signal. This field induces the E.M.F. in the mixer coupling loop.

This is the way electromagnetic energy is transmitted from the loop of the T-junction to that of the mixer, i.e. from the antenna to the crystal mixer. The magnitude of the transmitted energy depends upon the accuracy with which the cavity circuit is tuned to resonate with the magnetron frequency. If the cavity circuit is considerably detuned, transmission of electromagnetic energy from one loop to the other becomes practically impossible. Therefore the radar detection range is largely dependent on the tuning of the cavity circuit and its coupling to the receiver mixer.

The operation of the T.R. cell during reception at frequencies approximating the resonant frequency, may be illustrated by an equivalent diagram presented in Fig.57, c.

During the magnetron operation the T.R. cell functions differently. Part of the transmitter pulse energy is passed through the coupling loop to the T.R. cell; in this case a great A.C. voltage is developed between the discharger cones which causes breakdown of the gap between them. Due to the breakdown the T.R. cell cavity circuit is detuned and as a result the conditions of energy transmission from the coupling loop of the T-junction to that of the mixer are impaired. However part of the energy penetrates to the receiver and the tube screens of the range and plan-position indicator display a direct pulse marker.

To neutralize the T.R. cell affect on energy transmission towards the antenna the length of the arm connecting the T.R. cell to the radio-frequency feeder should ensure the infinity of the arm input resistance on the T-junction side with the detuned T.R. cell connected to it.

The gap between the cones is broken down at the instant the magnetron begins to generate and the discharge continues as long as there is generation.

.../After the

After the magnetron has stopped operating the discharge between the cones ceases and the cavity circuit is returned to its initial resonance state.

6. ANTENNA

The antenna is composed of a parabolic reflector and an antenna head. The parabolic reflector is a rigid metal structure. The paraboloid reflecting surface is perforated to decrease its weight and wind resistance without a noticeable change in rigidity and reflecting power. The diameter of the reflector is 1.5 m., and the focal distance is 0.441 m.

The parabolic reflector is oriented with regard to the reference voltage generator in such a manner that its geometrical axis coincides with the axis of the antenna head rotation.

The antenna head (Fig.58) consists of half-wave asymmetrical dipole 1, reflecting disc 2, quarter-wave transformer 7 and quarter-wave bazooka 8. One half of the dipole is attached to the outer conductor of the feeder, the other half to the inner conductor and passes through a hole cut in the outer conductor.

The reflecting disc is a brass disc fixed to protruding part 11 of the antenna head feeder. The feeder protruding part is a short-circuited stub and serves to secure the inner conductor of the antenna feeder.

The dipole, quarter-wave bazooka and reflecting disc are placed in polistyrene housing 6, which is required to make the antenna feeder hermetically sealed.

To blow the antenna head with dry air provision is made in the protruding part of the inner conductor for hole 5 which during operation is closed with cap 3.

The dipole intended for radiating the parabolic reflector is connected asymmetrically to the radio-frequency feeder. One rod of the dipole is directly connected to the current-carrying surface of the feeder conductor. The other rod is connected to the current-carrying surface of the feeder second conductor through the edges of the hole in the tubular conductor

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.../and through

and through the tubular conductor outer surface elements located near the hole.

Asymmetrical excitation of the dipole results in asymmetrical (in relation to the axis of the head rotation) distribution of electromagnetic energy radiated by the dipole, thus, the dipole centre of radiation being displaced in relation to the axis of rotation towards the rod connected to the outer conductor.

That part of radiated energy which falls on the reflecting disc is directed towards the parabolic reflector. The parabolic reflector concentrates it into a narrow beam and directs it into space. Thus, more high gain factor of the antenna in the direction of the axis of the radiation pattern is obtained. Due to leakage of electromagnetic energy through the hole in the outer conductor and due to direct connection of the conductor external surface to one of the dipole rods high-frequency currents are developed on the outer conductor external surface. These currents may travel over the outer conductor towards the parabolic reflector and distort the radiation pattern.

To keep these currents out of the parabolic reflector a quarter-wave bazooka with an input resistance equal to infinity is fitted over the outer surface of the feeder.

The parabolic reflector concentrates the energy radiated by the antenna head into a beam, whose axis is tilted with respect to the reflector axis, because the antenna head centre of radiation is slightly displaced from the reflector axis.

When the antenna head is rotated the position of the beam in space changes and its axis traces a cone surface. The radiation intensity is maximum in the direction of the beam axis and decreases away from the axis.

The radiation intensity in various directions is characterized by the radiation pattern shown in Fig.59.

.../It should

It should be noted that at small elevations of the parabolic reflector with regard to the earth's surface, a considerable part of the energy radiated by the antenna strikes against the earth surface, which is rather a good reflector for ultra-short radio waves.

As a result of the imposition (interference) of radio waves radiated into space direct from the antenna and reflected from the earth's surface the antenna radiation pattern sharply changes, and breaks (in vertical plane) into a number of lobes.

Consequently, with the angles between the target direction and earth surface level below 1-00 the accuracy of the target tracking in angular coordinates decreases and at a certain value of the angle the automatic target tracking is out of the question.

The input resistance of the antenna is matched with the output resistance of the radio-frequency feeder by means of quarter-wave transformer 7 (Fig.58) designed as a boss of the feeder inner conductor.

It should be borne in mind that matching of the antenna with the feeder and inclination of the radiation pattern axis with respect to the geometrical axis of the reflector are largely dependent upon the distance between the dipole and quarter-wave bazooka 8, upon the distance between the dipole and the reflecting disc as well as upon the length of the short-circuited stub in protruding part 11 of the feeder. Therefore, any arbitrary alterations in dimensions and mutual location of separate elements of the antenna head are not allowed.

The input resistance of the antenna, dependent upon the position of the quarter-wave bazooka and reflecting disc with regard to the reflector as well as upon the length of the short-circuited stub, changes with the alteration in frequency. This results in decrease of the TWR of the antenna-feeder system.

The length of the short-circuited stub, the distance from the dipole to the quarter-wave bazooka and reflecting disc should ensure variation

of the antenna input resistance (with the change of frequency) within the range providing the TWR is not below 0.65. At the same time the deflection angle of the beam axis in respect of the reflector axis is about 0-23.

Chapter 4

RECEIVING SYSTEM

1. GENERAL

The receiving system serves to convert and amplify the target echo signals picked up by the antenna to a magnitude required for normal observation of these echo markers on the screens of the range and plan-position indicators as well as for operation of the automatic range finder units and the antenna positioning system.

The receiving system consists of a signal mixer, an automatic frequency control (AFC) mixer, and three units: an intermediate-frequency preamplifier, an automatic tracking channel amplifier and a range channel amplifier.

Both mixers are coupled with the elements of the antenna-feeder system. The intermediate-frequency preamplifier unit is located in the transmitter cabinet, whereas the remaining units - in the cabinet of the main control board.

The receiving system utilizes a superheterodyne circuit. To maintain constancy of differential frequency of the local oscillator and the magnetron in the course of operation the receiving system is provided with automatic frequency control (AFC).

2. BLOCK-DIAGRAM

Electromagnetic pulses of ultra-high frequency (2700 to 2860 Mc/sec.) returned from the target as echoes are picked up by the antenna and conducted through the antenna feeder and T.R. cell to the signal mixer

.../(Fig.61).

(Fig.61). The mixer is also supplied by the microwave local oscillator with voltage of sustained oscillations having a frequency which differs from the picked-up by the value of the intermediate frequency of 30 Mc/sec. These two frequencies are heterodyned within the mixer to produce I.F. voltage. This voltage, amplified by three stages (V22-8, V22-9, V22-10) of the preamplifier located in the I.F. preamplifier unit, is applied to the automatic tracking channel amplifier unit through the radio-frequency cable.

The signal is furnished to the AFC mixer from the transmitter through a cut-off attenuator which ensures the required pulse attenuation. The AFC mixer is also supplied by the microwave local oscillator (V22-22) with voltage of sustained oscillations having a frequency differing from the frequency of the echo oscillations by the value of the intermediate frequency of 30 Mc/sec. These two frequencies are heterodyned within the mixer to produce I.F. voltage of 30 Mc/sec. The AFC mixer output is applied to the I.F.A. input of the AFC channel, amplified by three I.F.A. stages (V22-1, V22-2, V22-3) and is furnished to the discriminator (frequency-sensitive detector V22-4). The discriminator produces a voltage whose value is proportional to the deviation of intermediate frequency of 30 Mc/sec from the rated, while the voltage polarity depends upon the sign of drift of intermediate frequency in relation to its rated value of 30 Mc/sec. This voltage amplified by the pulse amplifier (V22-5) acts on the control circuit formed by diode V22-6 and a saw-tooth oscillator - a phantastron (V22-7). The output voltage of the control circuit controls the frequency of the klystron oscillator so that voltage of the rated intermediate frequency of 30 Mc/sec is obtained at the output of the signal mixer.

The I.F. preamplifier unit accommodates a local oscillator (V22-22) with stabilized rectifier -250 V (V22-14 to V22-18) and -255 V, V22-19 to V22-21), and a +150 V rectifier (V22-11) supplying the stages of the I.F. preamplifier and some stages of the AFC channel.

In the automatic tracking channel the I.F. signal is amplified by four I.F.A stages (V1-1, V1-2, V1-3, V1-4) which are the fourth, fifth, sixth and seventh stage of the I.F.A. of the receiving system. After the fourth (seventh) stage the signal travels along the two channels: automatic tracking and range channels.

The automatic tracking channel is triggered only when the very narrow gate of 0.3 microseconds duration furnished from the range unit is acting on the fifth (eighth) intermediate-frequency amplifier stage. Therefore, the automatic tracking channel passes only those pulses which are synchronized with the very narrow gate. The signal in the automatic tracking channel is amplified by two I.F.A. stages (V1-5, V1-6) detected by the diode detector (V1-7) and amplified by two video amplifier stages (V1-8, V1-9). From the output of the video amplifier (V1-9) the amplified negative pulses are applied to the automatic gain control circuit and to the automatic tracking and automatic range finder units.

The automatic gain control (AGC) circuit is designed to maintain a constant amplitude of the signal at the output of the receiving system. This is required for proper operation of the antenna positioning system. If the input signal is largely varied, the output voltage of the AGC circuit changes the bias voltage on the control grids of the first (fourth) and second (fifth) I.F.A. stages (V1-1, V1-2) in such a way that the level of the receiving system output remains approximately constant.

Apart from the above stages, the amplifier unit of the automatic tracking channel accommodates one I.F.A. stage of the range channel (V1-11) whose output signal is furnished to the input of the range channel amplifier unit, and a stabilized voltage rectifier, +120 V, (V1-12 - V1-15) to supply some valves of the I.F. amplifier (V1-1 to V1-5, V1-11).

In the range channel amplifier unit the signal is amplified by an I.F.A. stage (V2-1), detected by the diode detector (V2-2), amplified by

.../three video

three video amplifier stages (V2-3, V2-4, V2-5) and is conducted to the range indicator unit, plan-position indicator unit and automatic range finder unit.

The range channel amplifier unit contains rectifiers for +300 V (V2-7, V2-8) and for -105 V (V2-9) which are used to supply the valves of the given unit and of the amplifier unit in the automatic tracking channel.

3. SIGNAL AND AFC MIXERS

The signal mixer (Fig.61) is located between the T.R. cell and the microwave local oscillator and is rigidly coupled with the T.R. cell by means of plate 11 secured with screws.

The signal mixer includes: cartridge 1 with a germanium mixer diode (type DG-S1) inserted into coaxial line 2 which is connected to the T.R. cell by means of . . . . (one whole page missing)

To obtain the required sensitivity of the receiving system it is necessary to choose an operating point with maximum steepness on the current-voltage characteristic of the crystal diode, since in this case the required conversion factor is provided.

The position of the operating point is determined by optimum value of the crystal diode current which in turn is determined by the power applied from the oscillator (as the signal power is very small and practically does not affect the crystal current).

The crystal diode current should be selected at minimum coupling with the oscillator and at maximum matching of the oscillator with the mixer. Minimum coupling with the oscillator is achieved by lifting up capacitive disc 7 when adjusting screw 5 is rotated counter-clockwise. The oscillator is matched with the mixer by selecting a definite length of the connecting line with the help of trombone 4.

Thus by selecting the above values the oscillator may be caused to produce maximum power output at sufficiently weak coupling with the mixer

.../and at

and at the required current of the crystal diode (optimum current value is within the range of 0.2 to 0.6 mA). This results in reduction of the signal energy loss in the oscillator circuit. Besides, minimum noise voltage from the oscillator penetrates into the mixer.

The AFC mixer (Fig.62) is screwed on the cut-off attenuator which is rigidly coupled with the T-junction of the feeder line by means of a nut 7.

The mixer includes: cartridge 1 with a crystal diode of the DG-S1 type, placed in coaxial line 2, which is coupled to the cut-off attenuator with the aid of coupling loop 3; 50-ohm washer 4 used to match the mixer with the microwave oscillator; coupling adjusting screw 5; output connector 6 which accommodates a R.F. filter.

The AFC mixer is similar in the operating principle to the signal mixer.

Coaxial line 2 is provided with a nut 7 by means of which the mixer is moved along the cut-off attenuator.

The cut-off attenuator comprises a section of a cylindrical waveguide having great attenuation for the transmitter frequency band. The value of the transmitter signal attenuation is proportional to the waveguide length.

The signal value required for the normal operation of the AFC channel is selected by shifting the mixer so as to achieve the most advantageous position of the coupling loop in the attenuator.

The matching of the coupling line of the mixer with the oscillator by means of the 50-ohm washer makes it possible to obtain the crystal diode current of not less than 0.2 mA in the operating frequency band of the station, which is enough for the mixer normal operation. The AFC mixer should not be highly sensitive, as the value of the signal applied to the mixer can be regulated by varying the position of the mixer coupling loop in the cut-off attenuator.

The cut-off attenuator (Fig.63) is designed as a cylindrical tube (waveguide) soldered at an angle of 30° to the coaxial feeder.

.../4. INTERMEDIATE-FREQUENCY

4. INTERMEDIATE-FREQUENCY PREAMPLIFIER (I.F.P.) UNIT

The I.F.P. unit is located in the transmitter cabinet. The unit chassis carries a microwave oscillator with a supply rectifier, an I.F. preamplifier and elements of the AFC channel.

A key diagram of the I.F. preamplifier unit is shown in Fig.64 (see Album). The front panel of the unit is presented in Fig.65, while its top view - in Fig.66.

Microwave Oscillator

The microwave (klystron) oscillator serves to produce radio-frequency sustained oscillations having a frequency differing from that of the magnetron by the value of the intermediate frequency of 30 Mc/sec within the operating frequency band of the transmitter (2700 to 2860 Mc/sec.).

The radio-frequency oscillator connected as a microwave oscillator (Figs 67, 68) consists of a special valve, called klystron, and a cavity circuit (resonator).

The circuit is formed by part of the cavity enclosed between the grids inside the klystron and metal body 4 of the cavity circuit, in which the klystron is encased.

The klystron, type K-11, used in the station consists of a heated cathode, a control (accelerating) grid, two resonator grids and a repeller.

The klystron control grid connected with the resonator grids and the cavity circuit is supplied from the stabilizer output with a positive (with respect to the klystron cathode) voltage of +250 V. The repeller is fed with a negative (with respect to the cathode) voltage adjustable from -40 to -170 V.

The klystron functions as follows:

Electrons emitted from the cathode are accelerated by the positive potential on the control grid until they enter the space in the cavity of the central part of the resonator (cavity circuit). After that they pass

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.../between the

between the two resonator grids. A variable electric field of radio-frequency oscillations set up in the cavity circuit at the instant when the klystron is switched on or due to fluctuation of the electron flux density, accelerates the electrons for one half-cycle and retards them for the second half-cycle.

In connection with it some electrons travel into the space between the resonator grids and the repeller with increased velocity $v_0 + v_1$ while others with decreased velocity $v_0 - v_1$.

The electrons that pass between the resonator grids at the instant when the variable field is zero travel into the space between the grids and the repeller with the same velocity v_0, which have all the electrons approaching the resonator grids.

Thus, after passing the resonator grids the electrons in the beam appear to be velocity-modulated. In the space between the resonator grids and the repeller the electrons are acted on by the field of the repeller electrode charged negatively and tending to return the electrons back to the resonator grids. The electrons with different velocities have different trajectories in the drift space. The electrons with higher velocities approach the repeller closer than those with lower speeds. At a definite relationship of voltages across the klystron grids and the repeller, the electrons with both higher and lower velocities return to the resonator grids simultaneously (Fig.69). Thus, velocity modulation of the electron flow converts into density modulation.

Separate bunches of electrons formed as a result, while returning to the grids of the resonator give up part of previously stored energy to it. This occurs during the half-cycle of oscillations when the resonator electric field retards the motion of electrons towards the cathode.

From this it can be seen that sustained oscillations in the klystron may be excited at definite matching of the transit time from the resonator

.../grids to

grids to the repeller and backwards with a cycle of the resonator self-oscillations.

At the assigned oscillation frequency of the resonator this matching is achieved due to the change of potential on the klystron repeller.

The oscillator frequency depends upon the dimensions of the cavity circuit (resonator). The change in the circuit cavity is obtained by the aid of four threaded plugs 8 (Fig.68) inside the resonator. By these plugs the oscillator is tuned to the required frequency and the frequency is adjusted when the magnetron is replaced.

The fifth plug (11) is coupled to knob 9 which is brought out to the front panel of the unit and is marked KLYSTRON FREQUENCY. By means of this plug the oscillator wavelength is regulated at any section of its operating band within the range of not less than 0.2 cm.

The cavity circuit of the klystron incorporates three coupling loops. Two of them are used to conduct the radio-frequency power through coaxial cables to the crystal signal and AFC mixers. The third loop is connected through the coaxial cable to the connector located on the front panel and marked CONTROL CONNECTOR. The connector is coupled to the echo box by means of which the oscillator frequency is measured.

Presence of current in the circuit of mixers is determined by instrument Pp22-1 (CRYSTAL CURRENTS) situated on the front panel of the I.F. pre-amplifier unit (Fig.65). To measure the crystal currents of the signal and AFC mixers the instrument is switched over by means of selector switch 9 marked CRYSTAL CURRENTS (W22-3). Maximum power is taken from the klystron when the coupling loop is located in the vertical plane.

Sustained oscillations may be maintained in the klystron at several different voltages impressed on the repeller.

The klystron, type K-11, employed in the station has within the operating band two or three regions of generation to which correspond the

.../following potentials

following potentials on the repeller (relative to the cathode):

first region from -20 to -40 V;

second region from -50 to -140 V;

third region from -170 to -250 V.

The value of maximum power produced by the klystron, and the range of electronic tuning change depending upon a region of generation (Fig.70, a, b).

For klystrons, type K-11, the second region of oscillations is the most stable. It has higher power and wider range of electronic tuning as compared with the first and third regions. Therefore, the range of voltage regulation on the repeller is selected (from -40 to -170 V relative to the cathode) so as to excite oscillations of the second region, the first and third regions being used partially.

To achieve high stability of the frequency of oscillations the repeller and the resonator of the klystron are fed with stabilized voltages.

Voltage is applied to the klystron repeller through a divider formed by resistors R22-58 and R22-60 which are connected to the sliders of potentiometers R22-56 (REPELLER VOLTAGE) and R22-59 (ZONE SELECTION). These potentiometers are in parallel with stabilovolts V22-20 and V22-21 which stabilize the voltage from a -255 V rectifier employing valve V22-19 (5C4S).

The klystron resonator is fed with a stabilized voltage of +250 V (relative to the cathode) from an electronic regulator utilizing valves V22-16, V22-17 and V22-18 (Fig.71).

The input of the electronic regulator is fed with voltage from the rectifier using valve V22-14 (5C4S). The plus of the regulator is earthed whereas the minus is connected with the klystron cathode. Valve V22-16 (6P3S) is an automatically controlled variable resistor placed in series with the load circuit of the regulator. Valve V22-18 (6Z8) controls valve V22-16. The control grid of valve V22-18 is supplied with a portion of the regulator output voltage from the slider of potentiometer R22-50

.../RESONATOR VOLTAGE

RESONATOR VOLTAGE SETTING placed in the circuit of a divider formed by resistors R22-49, R22-50, R22-51. This divider is connected in parallel with the load.

If, for some reason, the output voltage increases, the potential on the grid of valve V22-18 rises with resultant rise of the plate current of valve V22-18 and increase of the voltage drop across resistor R22-45. The plate voltage of this valve decreases. The voltage on the control grid of valve V22-16 decreases, since it is connected through resistor R22-46 with the plate of the control valve. This lends to an increase of differential resistance of valve V22-16 and to an increase of the voltage drop across it, and consequently to redistribution of the voltage applied from the rectifier between valve V22-16 and the load. In this case the voltage across the load decreases to the rated value.

If the output voltage decreases an opposite process takes place.

The cathode of control valve V22-18 has a constant potential of +150 V due to voltage drop across regulator V22-17 (5C4S). This has been done to ensure more complete transmission of changes in the output voltage to the grid of the control valve and simultaneously to ensure normal bias on its grid (otherwise the grid would be under high positive potential relative to the cathode).

Capacitor C22-44 is designed to raise the efficiency of the regulator circuit with regard to quick fluctuations of the regulator output voltage caused by a quick change in load current or output voltage. At changes with a frequency in the region of dozens of cycles per second or more, capacitor C22-44 has a low resistance as compared with the resistance of the upper arm of the divider formed by resistors R22-49, R22-50, R22-51. As a result, the A.C. components of the output voltage are almost entirely applied to the control grid of valve V22-18.

The regulator output voltage can be adjusted by shifting the slider of potentiometer R22-50. The shaft of potentiometer R22-50 is brought

.../out to

out to the front panel and is marked RESONATOR VOLTAGE SETTING (Fig.66). By rotating this shaft, the voltage on the cathode-resonator section of the klystron, measured between monitoring jack G22-2 (-250 V) and the chassis, is set equal to -250 V.

The receiving system can function in two modes of operation: automatic frequency control and manual frequency control. The desired mode is selected by means of switch W22-4 whose knob is brought out to the front panel of the I.F. preamplifier unit and is marked MANUAL - AFC (8, Fig.65). When the station is operating, the knob should be set in position AFC, since in the course of operation, especially immediately after the start, the frequency of the klystron and magnetron may greatly change which would necessitate frequent adjustment of the klystron.

The negative voltage on the klystron repeller at manual frequency control (Fig.72) is determined by the positions of potentiometers R22-56 (REPELLER VOLTAGE) and R22-59 (ZONE SELECTION).

During AFC mode of operation the slider of potentiometer R22-56 (REPELLER VOLTAGE) is disconnected from the klystron repeller, and a plate load circuit of the saw-tooth oscillator valve (V22-7) is connected to it. In this case the voltage on the repeller is determined by the voltages of potentiometer R22-59 (ZONE SELECTION) and the saw-tooth oscillator.

Presence of two potentiometers R22-56 (REPELLER VOLTAGE) and R22-59 (ZONE SELECTION) adjusting the voltage on the repeller makes it possible to carry out initial tuning of the oscillator (at manual frequency control) by means of both potentiometers so that during automatic frequency control saw-tooth voltage will be located symmetrically relative to the region of the klystron frequency.

The unit supply circuits are energized by two switches W22-1 (HEATER) and W22-2 (PLATE) situated on the front panel of the unit (10 and 11, Fig.65). When turning on switch W22-1 a neon lamp, +150 V (N22-13) comes on; when

.../turning on

turning on switch W22-2 a neon lamp, +250 V (N22-15) comes on. Both lamps are located on the front panel of the unit.

Intermediate-Frequency Preamplifier

The I.F. preamplifier serves to amplify the echo signal voltage. The value of amplification is selected in such a way that loss in the long junction cable through which the signal is conducted to the amplifier of the automatic tracking channel will not reduce the receiving system sensitivity.

The input of the I.F. preamplifier is very close to the crystal mixer. This excludes the possibility of appreciable weakening of the signal in the junction cable between the mixer and I.F. preamplifier and consequently, decrease of the signal-to-noise ratio at the input of the receiving system.

The I.F. preamplifier is comprised of three stages. The first two stages utilize 6Z1P valves (V22-8, V22-9) in a circuit: earthed cathode-earthed grid (Fig.65). The use of this circuit is due to the fact that it has a very low noise factor and gives relatively high amplification and stability in operation.

The third stage (V22-10) employs a valve of the 6Z4 type with an oscillatory circuit placed in the plate circuit.

From the crystal mixer output the intermediate-frequency signal is conducted through the cable to the input circuit of the first I.F. preamplifier stage.

The two circuits of the first stage input circuit raise the output admittance of the crystal mixer to a value ensuring optimum signal-to-noise ratio on the grid of valve V22-8.

The primary circuit is formed by parallel-connected (for high-frequency) inductors L22-6, L22-9 and the capacitance of the mixer and cable connector coupling the input of the I.F. preamplifier to the mixer. Inductors L22-6 and L22-9 are wound on resistor R22-27 and R22-30 which do not impair

.../the circuit

the circuit quality factor noticeably, since the primary circuit quality factor is low due to shunting action of the crystal output resistance which is rather small (approx. 300 ohms).

Connected in series with inductor L22-6 are inductors L22-7, L22-8 wound on resistor R22-28, R22-29. These inductors together with capacitors C22-23, C22-24 constitute a radio-frequency filter in the crystal current circuit.

To measure D.C. component of the crystal mixer current use is made of milliammeter Pp22-1 placed in the current circuit between inductor L22-8 and earth. With switch W22-3 set in position AFC the instrument reads the value of the AFC mixer current, whereas with the switch in position SIGNAL, the value of the signal mixer current. The current value is determined by the power conducted from the oscillator to the crystal.

Capacitor C22-25 separates the control grid circuit of the valve from the D.C. circuit of the crystal mixer.

The primary circuit of the I.F. preamplifier input is tuned to resonate with the intermediate frequency. The secondary circuit is formed by the input capacitance of valve V22-8 (6Z1P) and inductor L22-10; the load from which the signal is applied to the valve grid is the input capacitance of valve V22-8. The circuit is tuned to the intermediate frequency by changing inductance of coil L22-10 with the help of a brass ring which is inserted into the coil. The ring is isolated from the chassis.

The plate load of the first stage valve (V22-8) is an oscillatory circuit consisting of inductor L22-11, the output capacitance of valve V22-8, the input capacitance of valve V22-9 and the capacitance of the wiring.

Inductor L22-12 neutralizes plate - grid capacitance of valve V22-8 thereby slightly improving the noise factor of the system and increasing the stability of the first stage operation.

Inductor L22-12 and the plate - grid capacitance of valve V22-8 constitute a parallel oscillatory circuit. The circuit is tuned to the

intermediate frequency by changing inductance of coil L22-12 with the help of an insulated brass ring.

Resistor R22-23 serves to obtain automatic bias on the grid of valve V22-9.

Capacitor C22-29 is a blocking type capacitor for intermediate frequency. D.C. component of the plate current of the second stage valve V22-9 based on an earthed grid circuit passes through resistor R22-33 and inductors L22-12, L22-10, L22-9. The plate load of the second stage is a circuit formed by inductor L22-13, the output capacitance of valve V22-10 the input capacitance of valve V22-9, and the capacitance of the wiring. The circuit is tuned to the intermediate frequency by changing inductance of coil L22-13 with the aid of a movable brass core.

Resistor R22-35 is leak for the control grid of valve V22-10. The value of this resistor shunting the circuit determines in the main the pass band and amplification factor of the I.F. preamplifier.

The I.F. voltage taken off the circuit is applied through capacitor C22-32 to the grid of the third stage valve V22-10 (6Z4). The equivalent circuit of the stage is presented in Fig.73.

The plate load of the third stage of the I.F. preamplifier is a parallel oscillatory circuit formed by inductor L22-14, the output capacitance of valve V22-10 and the capacitance of the wiring. Placed in series with this circuit is resistor R22-38 whose value is equal to the characteristic impedance of the cable connecting the output of the I.F. preamplifier with the input of the automatic tracking channel amplifier.

To make the circuit tuning independent of the length of the cable (its capacitance) and to keep losses at minimum during signal transmission the input resistance of the cable is made resistive. The cable is loaded by resistor R1-1 (75 ohms), connected at the input of the amplifier unit of the automatic tracking channel, whose value is equal to the characteristic impedance of the cable (cable, type RK-3, is used).

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At such a low input resistance of the junction cable it is better to place this resistance in series with the circuit as at parallel connection the circuit resistance proves to be inadmissibly reduced and the amplification factor of the I.F. preamplifier output stage is low.

The I.F. preamplifier valves are supplied from the +150 V rectifier located on the same chassis.

The rectifier is composed of valve V22-11 (5C4S) and transformer Tr22-3 (Fig.64). Choke D122-1 and capacitors C22-36, C22-37 constitute a filter. Resistor R22-62 and capacitor C22-46 comprise an additional filter in the circuit supplying the plates of the AFC channel valves. The rectified voltage is stabilized by stabilovolt V22-12 (SG4S) with resistor R22-40.

The stabilized voltage of +150 V is applied to the grids of the I.F. preamplifier valves. The presence of the rectified voltage is checked by means of indicating neon lamp MN-3 (V22-13) located on the front panel (+150 V).

Automatic Frequency Control (AFC) Channel

When the station is functioning the magnetron and klystron frequencies may largely vary due to changes in temperature, humidity, supply voltage, antenna rotation and a number of other factors. In this case the difference frequency deviates from the rated intermediate frequency and normal reception may be disturbed.

The AFC channel provides such trimming of the oscillator frequency at which the difference between the frequencies of the klystron and magnetron is kept approximately equal to the rated intermediate frequency of the receiving system.

The station employs an AFC search circuit. The AFC channel includes: an AFC mixer, I.F. amplifier stages, a discriminator, a pulse amplifier and a control circuit consisting of a saw-tooth oscillator (phantastron) and a diode.

.../In the

In the AFC channel, use is made of the signal directly furnished from the transmitter to the receiver (main pulse).

The signal is conducted to the AFC mixer through the cut-off attenuator of the waveguide type. The attenuator damping value is taken very large so as to reduce the main pulse power applied to the crystal to 1 - 2 mV.

The microwave oscillator output is applied to the mixer through the coaxial cable. After leaving the mixer the signal is conducted through a section of the coaxial cable to the primary winding of input transformer Tr22-1. Connected in series with the transformer primary winding is a R.F. filter in the measuring circuit of the crystal current D.C. component. The filter is formed by inductors L22-1, L22-2, wound on resistors R22-2, R22-3 and capacitors C22-1, C22-2.

The primary winding of transformer Tr22-1 with the capacitance of the wiring, the capacitance of connectors and the capacitance of the junction cable constitute a parallel oscillatory circuit tuned in resonance with the intermediate frequency of 30 Mc/sec.

When measuring D.C. component of the crystal mixer current (switch W22-3 in position AFC) an instrument, type Pp22-1, (CRYSTAL CURRENTS) is placed in the current circuit between inductor L22-2 and earth. The crystal current D.C. component is shorted through resistor R22-61 (100 ohms) equal to the internal resistance of the instrument.

The secondary winding of transformer Tr22-1 together with the input capacitance of valve V22-1 and the capacitance of the wiring constitute an oscillatory circuit tuned to the intermediate frequency by means of semi-variable capacitor C22-3.

To widen the pass band the secondary winding of the transformer is shunted by resistor R22-1 (300 ohms).

Transformer Tr22-1 is designed so that its primary winding may be moved relative to the secondary winding. By moving the primary winding it is

.../possible to

possible to vary the winding coupling factor and consequently the amplification factor of the AFC channel.

The use of a double input circuit with transformer coupling between the circuits reduces the influence of variation of the crystal mixer output resistance on the input of the first valve of the I.F. amplifier.

From this circuit the I.F. voltage is applied to the control grid of valve V22-1 of the first stage. The first and second stages of the I.F. amplifier (V22-1, V22-2) are based on resonance amplifier circuits using pentodes 6Z4 with oscillatory circuits in the plate circuits.

The oscillatory circuits are formed by inductors L22-3, L22-4, the capacitance of the wiring, output and input capacitances of the valves.

The circuits are shunted by resistors R22-6 and R22-9 (510 ohms) which determine the pass band and the amplification factor of the I.F. amplifier channel.

Placed in the cathode circuit of the first stage valve (V22-1) is variable resistor R22-63 equal to 1 kilohm. This resistor controls the channel amplification at intermediate frequency, its slotted shaft is brought out to chassis top and marked AFC AMPLIFICATION. Resistor R22-63 is included in the circuit of a divider formed by resistors R22-63 and R22-64.

Resistors R22-4, R22-7, R22-10 serve to develop automatic bias voltages on the control grids of the valves of the first, second and third I.F. amplifier stages due to the cathode current of the valves.

Connected into the plate circuit of the third stage valve (V22-3) is the primary winding of the transformer (Tr22-2) circuit of the discriminator (V22-4). The secondary winding of the transformer circuit is connected (with its ends) to the plates of the valve (6H6S) of the discriminator (Fig.74) producing output pulses whose polarity and value are determined by the magnitude and sign of detuning of the intermediate frequency relative

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to its rated value. The discriminator differently reacts to the signals whose frequencies are higher or lower than the rated.

The discriminator primary circuit is formed by capacitor C22-12, the output capacitance of the valve, the capacitance of the wiring and the primary winding of transformer Tr22-2; the secondary circuit - by capacitor C22-14 and the secondary winding of transformer Tr22-2.

The primary and secondary circuits of the discriminator are tuned to the intermediate frequency of 30 Mc/sec. As the coupling between the circuits is weak the resonant frequencies of the circuits are determined in the main by their own parameters.

The quality factor of the primary circuit is low, therefore within a certain range near the intermediate frequency, the dependence of voltage E_1 across the circuit upon the frequency is negligible.

Voltage E across the secondary circuit is also relatively constant in value within this frequency band and is in phase with E_1.

Current I_2 is induced in the secondary oscillatory circuit which develops a voltage across the secondary winding of transformer Tr22-2:

$$E_2 = I_2 X_{L_2},$$

where X_{L_2} is inductive resistance of the secondary winding.

The value and phase of voltage E_2 vary with the change of the frequency, since the character of the circuit impedance depends upon the frequency.

Each diode of the discriminator valve is fed with A.C. voltage equal to the geometrical sum of oscillatory voltage $\bar{E}_1$ across the primary circuit and a half of voltage E_2 developed across the coil of the secondary winding. Vector diagrams of voltages in the discriminator circuits are shown in Fig.74, where

$$E_3 = E_1 + \frac{E_2}{2} \text{ and } E_4 = E_1 - \frac{E_2}{2}.$$

.../The secondary

The secondary circuit is tuned to the intermediate frequency of 30 Mc/sec, therefore at the input voltage of a frequency of 30 Mc/sec equal to the intermediate frequency voltages E_3 and E_4, as seen from the vector diagram, are equal in phase, and consequently, currents across the detector load (resistors R22-14 and R22-15) are equal in magnitude but opposite in direction. In this case the resultant voltage between point a and earth equals zero.

When the intermediate frequency deviates to one or the other side from the rated I.F. of 30 Mc/sec the phase shift between voltages E_1 and E_2 changes and voltages E_3 and E_4 will not be any longer equal in magnitude. Currents flowing through resistors R22-14 and R22-15 will also be unequal and the resultant voltage at the output of the discriminator detector between point a and earth will not be equal to zero. Depending upon the value and sign of detuning of the intermediate frequency relative to the rated, this resultant voltage at the discriminator detector output changes its value and has either positive or negative sign (Fig.75). The discriminator circuit is designed so that positive values of the output voltage are obtained at lower frequencies than the rated intermediate frequency of 30 Mc/sec, whereas negative values at frequencies higher than the rated intermediate frequency of 30 Mc/sec.

Thus, with the I.F. pulse voltage applied to the input of the discriminator, its output, depending upon the frequency of incoming signals, feeds out a train of positive or negative pulses of various amplitudes (Fig.76).

Such a form of the discriminator pulse response ensures proper operation of the AFC system only in case the oscillator frequency f_o is previously set higher than frequency f_m of the magnetron.

The functioning of the successive elements of the AFC system boils down to the following: the voltage pulses from the discriminator obtained

.../due to

due to deviation of the intermediate frequency from the rated value I.F. of 30 Mc/sec are amplified by a pulse amplifier (V22-5) and act on the control circuit, which produces a control voltage changing the klystron frequency. The control voltage changes the klystron frequency in such a way that the rated intermediate frequency is attained at the mixer output.

The control circuit is comprised by a saw-tooth oscillator (V22-7) and a diode (V22-6).

The saw-tooth oscillator employs pentode V22-7, type 6Z4, which when no pulses are applied to its input from the pulse amplifier (V22-5) functions as a self-excited oscillator (Fig.78).

Self-excitation of the saw-tooth oscillator is achieved due to capacitor C22-22 connected into the circuit. The capacitor provides coupling between the suppressor and screen grids. In the presence of such coupling an increase in the screen grid current causes negative voltage to appear on the suppressor grid and vice versa.

Discharge of capacitor C22-21 through valve V22-7 and a chain of resistors R22-20 and R22-23 raises the voltage on the valve control grid. This causes an increase in the plate current of this valve and a decrease in the voltage on its plate. The plate voltage drop is conducted through capacitor C22-21 to the control grid thereby slowing down the rise of the grid voltage and consequently the rise of the valve plate current and the voltage drop across the plate.

Any decrease of the discharge current results in a decrease of the negative voltage between the control grid and the cathode, which opposes the decrease of the discharge current.

Thus, due to strong feedback between the plate and the control grid through capacitor C22-21, the discharge current remains approximately constant, the plate voltage changes almost linearly.

This process goes on until the plate voltage drop reaches the value at which redistribution of the valve cathode current between the screen

.../grid and

grid and the plate takes place (Section b-c, Fig.77). The voltage on the plate decreases to 15 - 20 V relative to the cathode. In this case normal current distribution between the plate and screen grid is disturbed and the screen grid current begins to rise, and the grid potential - to fall.

A decrease of the voltage on the screen grid is conducted through capacitor C22-22 to the suppressor grid which brings about a further decrease of the plate current and an increase of the screen grid current and consequently an increase of the negative potential on the suppressor grid. This process is going on in an avalanche-like manner. As a result the negative voltage on the screen grid reaches such a value that the valve proves to be cut off for the plate current (point c, Fig.77). The plate voltage rises, so does the voltage on the control grid, thereby increasing the cathode and screen grid currents. In this case the voltage on the suppressor grid is negative relative to the cathode; valve V22-7 is completely cut off for the plate current, the voltage on the control grid is positive in relation to the cathode.

From this moment on capacitor C22-21 is being charged from the power supply through resistor R22-26 and grid - cathode section of the valve. The variation of the charge rate of capacitor C22-21 is determined by the values of resistor R22-26 and capacitor C22-21. The capacitor is being charged to a value approximately equal to the power supply voltage (Section c-d, Fig.77).

At the moment capacitor C22-21 starts to charge the control grid potential sharply rises to +2 - +4 V (Section b-c, Fig.77). Further rise of the grid voltage is limited by grid currents.

Capacitor C22-22 begins to discharge through the screen grid - cathode section and resistor R22-24. As the capacitor discharges the negative voltage on the suppressor grid decreases exponentially. The rate of discharge is determined by values of resistor R22-24 and capacitor C22-22.

.../At a

At a certain moment the voltage on the suppressor grid reaches the potential and takes the valve from the cut-off condition for the plate current (point d, Fig.77). The capacitance value of capacitor C22-22 is selected large enough so that the potential on the suppressor grid will not be able to recover until capacitor C22-21 is not charged to the voltage of the power supply and the voltage on the plate approximates that of the power supply E_a.

At the instant the valve becomes conducting for the plate current, the plate potential suddenly decreases by a value determined by product $I_a R_a$ (Section d-e, Fig.77). This sudden decrease of the plate voltage is conducted to the control grid through capacitor C22-21, which causes a decrease of the screen grid current, an increase of the voltage on the screen and suppressor grids and further rise of the plate current. This process is also going on in an avalanche-like manner, which results in the voltage being sharply raised on the screen and suppressor grids. The plate voltage decreases, so does the voltage on the control grid and at this moment it becomes almost equal to the cut-off potential for the plate current.

Capacitor C22-21 begins to discharge through the valve and resistors R22-20 and R22-23. As the capacitor discharges the potential on the control grid rises. The plate voltage decreases linearly and the entire process is being repeated.

Thus the saw-tooth oscillator produces saw-tooth voltage of about 3 to 5 c.p.s. (Fig.70, c) which is applied to the klystron repeller.

The klystron frequency, as was mentioned before, is set (during manual frequency control) higher than that of the magnetron frequency by the value of the intermediate frequency of 30 Mc/sec. With the saw-tooth variation of the oscillator voltage at the initial moment the negative voltage applied to the klystron repeller is small and, therefore, the difference

.../frequency $f_o - f_m$

frequency $f_o - f_m$ is less than the rated intermediate frequency (Fig.70, a). There are no pulses at the amplifier output. The saw-tooth oscillator searches for frequency.

As the negative voltage rises on the repeller, the oscillator frequency increases and the difference frequency enters the pass band of the I.F. amplifier of the AFC channel (Fig.70, e).

With the transmitter switched on, the pulse amplifier (in accordance with the discriminator response curve) produces first negative pulses to which the saw-tooth oscillator circuit does not respond (Fig.70, f).

The negative voltage on the repeller continues to rise and consequently the oscillator frequency increases. The difference frequency increases as well and passes zero point of the discriminator response curve (Fig.70, f) which is being set at the resonance frequency of the I.F. amplifier channels of the receiving system (30 Mc/sec).

The pulse amplifier (V22-5) produces positive pulses (Fig.77). They charge capacitor C22-20 through the control diode (V22-6).

When capacitor C22-20 discharges through resistor R22-20 during the pulse interval, a negative voltage (relative to the cathode of valve V22-7) is developed across this resistor. The voltage rises with an increase in the amplitude of the pulses applied to capacitor C22-20. At an instant when voltages across resistor R22-20 and the control grid of valve V22-7 become equal, the discharge current of capacitor C22-21 flowing through resistor R22-23 ceases, i.e. saw-tooth variation of the plate current ceases and the voltage that was present at the moment the saw-tooth voltage oscillations were stopped, is set up on the plate of oscillator V22-7.

Due to a large amplification factor of the AFC channel the saw-tooth voltage oscillations are stopped at inconsiderable deviation from the frequency corresponding to zero point on the discriminator response curve (0.2 to 0.3 Mc/s). At the moment of stopping the klystron frequency

.../ceases to

ceases to change (Fig.70, g). In this case an average voltage is impressed on the control grid of valve V22-7. The voltage maintains the oscillator frequency at such a level which ensures that the intermediate frequency equals the rated value.

From this moment the saw-tooth oscillator functions as a D.C. amplifier, i.e. the valve plate voltage follows the control grid voltage and automatically maintains the difference of the magnetron and oscillator frequencies equal to the intermediate frequency of the receiving system.

If the difference frequency exceeds the intermediate frequency of 30 Mc/sec positive pulses will be increased at the pulse amplifier output, which will result in an increase of the negative voltage on the grid of valve V22-7 and in an increase of the plate voltage. Therefore, the negative voltage on the klystron repeller will decrease and the klystron will generate lower frequency at which the difference frequency equals the intermediate one of 30 Mc/sec.

If the difference frequency decreases, positive pulses at the pulse amplifier output, while decreasing, will be cancelled out; capacitor C22-21 begins to discharge and the plate voltage decreases according to a saw-tooth law until positive pulses interrupting this change appear at the pulse amplifier output.

If the oscillator frequency, at the given polarity of the discriminator response curve, is set below the magnetron frequency, the search circuit will carry out tuning on a false point and keep the difference frequency unequal to the intermediate one of 30 Mc/sec, which will result in sharp reduction of the receiver sensitivity.

Diagram 78 illustrates the functioning of the AFC circuit when the oscillator is tuned to frequencies higher or lower than magnetron frequencies. Curves 1 and 2 show the relation of the voltage at the AFC circuit output (plate voltage of oscillator valve V22-7) to the oscillator (heterodyne)

.../frequency. Curves

frequency. Curves 3 and 4 show the relation of the oscillator frequency to the voltage on the klystron repeller during searching.

When the oscillator tuning frequency is lower than magnetron frequency, positive pulses at the output of the AFC channel, stopping the saw-tooth voltage of oscillator V22-7, appear at the difference voltage (of the magnetron and klystron) exceeding the rated intermediate frequency and the AFC circuit maintains the frequency other than the intermediate one (point B_1). Near point B_2 the circuit operation is unstable and any change in the klystron frequency detunes automatic frequency control. In point A the circuit function is stable.

The saw-tooth oscillator is supplied from two rectifiers (-250 and -255 V), located on the chassis of the I.F. preamplifier unit. These rectifiers are based on two kenotrons 5C4S (V22-14 and V22-19) and are used to supply the klystron and the saw-tooth oscillator.

The rectified voltage of -250 V is stabilized by the electronic regulator employing valves V22-16 and V22-18 whose operation has been analysed in detail in Section 3.

The rectified voltage of -255 V is stabilized by a series combination of stabilovolts SG3S and SG4S (V22-20 and V22-21).

When placing switch W22-4 in position AFC the voltage of -250 V is applied to the plate of valve V22-7.

Pin 2 of valve V22-21 is negative potential applied from the series combination of the rectifiers (-250 and -255 V), i.e. -505 V. This voltage is applied to the cathode of valve V22-7. Thus, a voltage of +250 V is applied between the plate and cathode of valve V22-7.

5. AUTOMATIC TRACKING CHANNEL AMPLIFIER

The automatic tracking channel amplifier unit (Figs 79, 80) is located in the upper left-hand part of the main control board cabinet.

A key diagram of the amplifier unit is presented in Fig.81 (See Album).

.../The automatic

The automatic tracking channel amplifier is designed for amplification of signals coming from the I.F. preamplifier. It is provided with two amplifier channels: a range channel and an automatic tracking channel. The signal from the output of the I.F. preamplifier (connector Zw22-6) is furnished through the coaxial cable with a characteristic impedance of 75 ohms to the input of the automatic tracking channel amplifier (connector Zw1-1) and then through coupling capacitor C1-1 to the control grid of valve V1-1.

Resistor R1-1 (75 ohms) as was mentioned above serves to match the input resistance of the first valve of the automatic tracking channel amplifier with the characteristic impedance of the cable.

The input circuit of the first stage of the automatic tracking channel amplifier is formed by inductor L1-1 together with the input capacitance of valve V1-1 (6Z4) and the capacitance of the wiring. The circuit is shunted by small resistance of R1-1 due to which it has a wider pass band as compared with the circuits of the successive stages, where the resistors shunting the circuits have considerably greater values (470 to 1000 ohms).

The first, second, third and fourth stages of the automatic tracking channel amplifier (V1-1, V2-2, V1-3 and V1-4) are the fourth, fifth, sixth and seventh stages of the I.F. amplifier in the receiving system respectively.

The I.F. amplifier stages in the unit are based on resonant amplifier circuits with parallel plate supply, using pentodes 6Z4, having oscillatory circuits in the control grid circuits.

In addition to inductors L1-1, L1-2, etc. the oscillatory circuits include interelectrode capacitances of the valves ($C_{input} + C_{output}$), the wiring capacitances (C_m) and inductor self-capacitances (C_{ind}). The total capacitance of the circuit is approximately 20 pF.

The control grids of the first two valves are fed with the negative voltage from the automatic gain control (AGC) circuit.

.../Resistors R1-4,

Resistors R1-4, R1-7, R1-11, R1-14, R1-19, R1-23 (Fig.81) that are the plate loads of the valves, are used to shunt the circuits and to determine the amplification factor and pass band both for the range channel and automatic tracking channel.

The circuits are tuned to the intermediate frequency by changing inductance of the coils with the help of movable brass cores. The initial bias on the valves of the I.F. amplifier stages of the automatic tracking channel amplifier unit is caused by the valve current flowing through resistors R1-3, R1-8, R1-10, R1-15, R1-22.

After the fourth I.F. amplifier stage of the automatic tracking channel amplifier unit the receiver amplifier channel is separated into two: the automatic tracking channel amplifier and range channel amplifier.

The automatic tracking channel amplifier is comprised of two I.F. amplifier stages (V1-5 and V1-6), a detector (left-hand diode of valve V1-7) and two video amplifier stages (V1-3 and V1-8).

The output voltage from the fourth I.F. amplifier stage (V1-4 of the unit is applied to the input of the fifth stage (V1-5). The fifth stage is usually cut off and is made conducting only when the screen grid of valve (V1-5) is supplied with the very narrow gate of 0.3 microsec. duration and 100 - 120-volt amplitude. The gate is furnished from the range and very narrow gate indicator unit through the cable via connector W11-5. When no very narrow gate is applied valve V1-5 is cut off by the negative voltage on the screen grid (about -100 V) taken from the voltage divider formed by resistors R1-60, R1-61 in the circuit of the -150-volt rectifier.

Therefore, the grid of the next sixth stage (V1-6) is supplied only with the voltage of the reflected signal that is timed with the very narrow gate.

The moment of feeding the voltage of the very narrow gate to the screen grid of valve V1-5 is set by the range operator who by operating

the handwheel aligns electronic markers on the fine range tube with the signal reflected from the selected target, thereby timing the voltage of the very narrow gate pulse with the reflected signal.

During automatic tracking of the selected target this alignment is done automatically by the follow-up system of the automatic range tracking.

Thus, only signals reflected from the target selected by the operator are amplified in the amplifier of the receiver automatic tracking channel.

Placed in the control grid circuit of valve V1-5 is resistor R1-17 to reduce the undesirable effect (caused by triggering and cutting off of the automatic tracking channel) on the parameters (amplification factor, pass band and resonance frequency) of the range channel I.F. amplifier.

The cathode circuit of valve V1-5 contains variable resistor R1-21 used for regulation of the automatic tracking channel I.F. amplifier. The resistor slotted shaft is brought out to the front panel of the unit and is marked AUTOMATIC SENSITIVITY CONTROL.

To extend amplification control range the cathode of valve V1-5 is supplied with additional bias from the divider formed by resistors R1-57 and R1-21 to which a stabilized voltage of +120 V is applied.

When AGC is functioning the resistance value of resistor R1-21 affects the amplification factor of the range channel. Should the resistance value, say, of R1-21 be increased the amplification factor of the automatic tracking channel will decrease. This will cause a decrease of the negative bias applied to the first and second I.F. amplifier stages from the AGC stage, and an increase of the amplification factor for these stages and, consequently, the amplification factor for the range channel, as the first and second I.F. amplifier stages of the automatic tracking channel amplifier unit are common for both channels of the receiving system.

When tuning the automatic tracking channel at the manufacturing plant or repair workshop, the screen grid of valve V1-5 is fed with a D.C.

.../voltage

voltage of +120 V. For this purpose jumper W1-3 is set in position +120 V. In position STROBE jumper W1-3 connects jack G1-3 with G1-4 and the very narrow gate is applied from the range indicator unit to the screen grid of valve V1-5. Total amplification of the intermediate frequency amplifier, from the input of the amplifier to the output of the ninth stage of the intermediate frequency amplifier of the automatic tracking channel, is about 200,000. The voltage from the ninth I.F. amplifier stage is applied to the second detector (valve V1-7) employing (to reduce the detector capacitance) one half of the double diode 6H6S; the other half of the valve is earthed. The detector load is resistor R1-26. Capacitor C1-32 and inductor L1-8 constitute a filter smoothing intermediate frequency ripples across the load resistor.

To monitor the operation of I.F. amplifier of the receiver automatic tracking channel during the receiver tuning, a microammeter may be connected into the D.C. component circuit of the detector current. For this purpose monitoring jack G1-1 (DIODE CURRENT) is provided whose contacts are connected to each other with the plug connector removed. The microammeter is shunted by resistor R1-28 (220 ohms) whose main function is to prevent discontinuity of the D.C. component circuit of the detector at the moment the contacts of jack G1-1 are opened.

The negative voltage pulses from the detector load are furnished to the input of the first stage of the video amplifier (V1-8). Both video amplifier stages operate as resistor-coupled amplifiers. The plate load of the first stage is resistor R1-30, the plate load of the second stage is resistor R1-35.

To correct the video amplifier frequency characteristic in the high-frequency region, chokes L1-9 and L1-11 are placed in the plate circuit of the first and second stages of the video amplifier. The choke resistance rises as the frequency increases, thus raising the total resistance of the plate load. This results in compensation of the resistance drop across

.../the load

the load caused by spurious capacitances. The use of correcting chokes at high frequencies extends the band of amplified frequencies which is necessary for undistorted amplification of short pulses applied to the video amplifier from the detector (Fig.83).

The negative voltage pulses are furnished from the plate of valve V1-9 through coupling capacitor C1-41 and resistor R1-37 to the cathode of the AGC detector (the left-hand triode of valve 6N8S), while through capacitor C1-40 - to connector W1-3, from where they are conducted to the automatic tracking and automatic range finder units.

One I.F. amplifier stage of the range unit (V1-11) located in the automatic tracking channel amplifier unit employs a valve of the 6Z4 type. The circuit of the stage is similar to that of the I.F. preamplifier, but the valve grid circuit contains an oscillatory circuit common with the fifth I.F. amplifier stage of the automatic tracking channel. The output voltage of this stage is applied to the range channel amplifier through connector W1-4.

Besides the described amplification channel the unit accommodates the AGC circuit (V1-10) and a rectifier with a +120-volt voltage stabilizer (V1-12, V1-13 and V1-14, V1-15).

Gain Control

The receiving system provides for manual and automatic gain control.

The automatic gain control, during automatic target tracking, provides the operation of the automatic tracking channel in the linear section of the receiving system amplitude characteristic. In this case the signal modulated by the error signal voltage is normally conducted through the receiving channel.

If the signal reflected from the target being tracked is excessively increased, the AGC circuit automatically reduces the amplification factor of the first and second I.F. amplifier stages of the automatic tracking

.../channel amplifier

channel amplifier unit due to the additional negative bias voltage applied to the valve grids of these stages.

During automatic tracking of the target in angular coordinates the receiving system gain is controlled only automatically. In other modes of operation manual control is used. The AGC circuit consists of a detector - the left-hand triode of valve V1-10 (6N8S) connected as a diode, and a D.C. amplifier with a cathode load employing the right-hand triode of the same valve. The triode grid is connected to the middle contact of relay P1-1.

When setting selector switch (W12-1) (MODE OF OPERATION) located in the antenna control unit in position (AUTOMATIC) the winding of relay P1-1 is supplied with A.C. voltage (110 V, 50 c.p.s.), contacts 5-6 of the relay close and the grid of the AGC amplifier is supplied with voltage from the load of the AGC detector (divider R1-46, R1-45, R1-42). In this case the receiver operates with AGC (Fig.84).

The cathode of the left-hand triode of valve V1-10 (AGC detector) is supplied with a positive D.C. voltage of +30 V from divider R1-39, R1-40, fed with a stabilized voltage of +120 V.

In the absence of the signal from the output of the receiver automatic tracking channel, the detector plate is under a small negative (in relation to earth) potential (approximately -2 V) taken from the voltage divider composed of resistors R1-43, R1-44, R1-42 (in the automatic tracking channel) and R7-99 (in the automatic range finder unit) fed by a stabilized voltage -105 V. Therefore, the AGC detector is cut off by a negative voltage of about 32 V. In this case there is no voltage drop across the load (R1-45, R1-46) of the detector and, consequently, the grid potential of the D.C. amplifier (the right-hand triode of valve V1-10) is approximately -2 V.

The AGC amplifier is connected as a cathode-loaded stage (R1-41). The plate voltage of this stage is attained by adding stabilized voltages of +120 and -105 V and makes up about 225 V.

SECRET

.../The resistance

The resistance value of resistor R1-41 should ensure a voltage drop of 105 V across the resistor during the plate current flow through the valve (at the grid potential of about -2 V). In this case the AGC resultant voltage on the grids of the first and second stages of the I.F. amplifier equals zero, while the bias voltage of these stages is determined by the voltage drop across the resistors in the circuits of the valve cathodes. The receiving system provides maximum gain.

The initial zero voltage is set on the grids of the first and second I.F. amplifier stages with the help of potentiometer R1-42 whose slotted shaft is brought out to the unit chassis and marked AGC SETTING.

If the amplitude of the negative pulses at the output of the receiving system automatic tracking channel exceeds 32 V the AGC detector is triggered by the pulses. Capacitor C1-44 is being charged through the diode and resistor R1-37. In pulse intervals capacitor C1-44 is being discharged through the detector load resistor R1-46, R1-45, R1-42. The time constant of the capacitor charging circuit makes up 5 microseconds which exceeds the duration of the output pulse (of the receiving system automatic tracking channel) equal to 0.3 microseconds.

The time constant of the capacitor discharging circuit makes up 6200 microseconds, which considerably exceeds the duration of pulse intervals which are approximately 533 microseconds. As a result the voltage across capacitor C1-44 under steady conditions remains almost constant slightly changing by the action of pulses at the receiver output.

The more the pulse amplitude at the output of the receiving system the greater the value of the voltage across capacitor C1-44.

The voltage across capacitor C1-44 is set (when the amplitude of pulses at the receiving system output is invariable) at such a level at which the electricity obtained by the capacitor for a period of the pulse travel through the charging circuit, equals the electricity lost by the capacitor in the discharging circuit during the pulse interval.

SECRET

.../The voltage

The voltage caused by discharge of capacitor C1-44 is taken from resistor R1-45 to the grid (4) of the right-hand triode of valve V1-10 (AGC amplifier). Thus, if capacitor C1-44 proves to be charged due to the AGC detector operation, to a voltage exceeding the voltage drop across resistor R1-42, approximately one quarter of this additional negative voltage is conducted to the grid (4) of the D.C. amplifier. The valve plate current decreases. The voltage drop across resistor R1-41 becomes less than 105 V and the valve cathode potential drops below zero. This negative voltage is applied to the valve grids of the first and second I.F. amplifier stages of the automatic tracking channel amplifier unit and causes a reduction of amplification factors of these stages and consequently of the entire receiving system.

Thus, as the amplitude of echo signals increases the AGC system automatically reduces the amplification factor of the receiving system and protects separate stages from overloads.

Connected to the input of the right-hand triode of valve V1-10 (AGC amplifier) is capacitor C1-45. The time constant of the charging and discharging circuits of capacitor C1-45 through resistors R1-46, R1-45, amounts to several seconds. As a result at rapid changes of the pulse amplitude at the output of the receiving system automatic tracking channel the voltage on the grid of valve V1-10 and consequently the output voltage of the automatic gain control remain practically constant, because these voltages depend on the average level of the signal at the output of the receiving system.

In particular, due to application of capacitor C1-45, the AGC system does not react on ripples of the echo pulse amplitude with a frequency of 24 c.p.s. caused by deviation of the antenna axis from the target direction and thus does not reduce the error voltage used for the antenna automatic control.

SECRET

.../Manual gain

Manual gain control. With selector switch W12-1 MODE OF OPERATION in position MANUAL the relay winding is de-energized, contacts 6-7 of relay P1-1 (Fig.84) close and the grid of the D.C. amplifier is fed with the voltage from a series combination of potentiometers R1-44 and R7-99, whose knobs are brought out to the front panel of the amplifier units of the automatic tracking channel and automatic range finder and marked GAIN (R1-44 and R7-99).

In this case the AGC detector is switched off and gain is controlled manually.

By rotating knobs of potentiometers R1-44, R7-99 it is possible to change the voltage on the grid of the right-hand half of valve V1-10 (AGC amplifier) and consequently the output voltage taken from the cathode and the bias voltage on the valve control grids of the two first stages of the automatic tracking channel amplifier unit.

When turning knobs R7-99 and R1-44 to their extreme clockwise positions the voltage on the grid of the right-hand half of valve V1-10 (AGC amplifier) relative to earth will be equal to the voltage drop across resistor R1-42 (-1.5 to -2 V), i.e. will be the same as that during automatic gain control with the AGC detector cut off.

In this case the circuit output voltage, i.e. the voltage between the cathode of the AGC amplifier and earth, equals zero and the receiving system operates with maximum amplification factor.

When rotating knobs GAIN (R1-44) and GAIN (R7-99) counter-clockwise the grid potential of the D.C. amplifier decreases and consequently the circuit voltage becomes negative which results in decrease of the receiver amplification factor.

Voltage Stabilizer

For stable operation of the receiving system the plate circuits and screen grids of the I.F. amplifier stages of the automatic tracking channel

amplifier unit are supplied from the voltage stabilizer mounted on the chassis of the automatic tracking channel amplifier unit.

Stabilization of voltage in the given circuits protects the operation of the receiving system from the oscillations of the mains primary voltage and change of the load current.

The input of the voltage stabilizer, composed of regulating valve V1-13 (GU-50) and control valve V1-14 (6P9) is supplied with a voltage of about 360 V from the rectifier output (Fig.81, See Album).

The stabilized voltage is regulated by changing the resistance value of resistor R1-54 with the help of slotted shaft +120 V brought out to the chassis; the slotted shaft is set so that the voltage at the stabilizer output is equal to +120 V.

The operating principle of the stabilizer is described above (See Section 4).

The presence of the rectified voltage is checked with the aid of the neon lamp N1-17 (+120 V) located on the front panel of the assembly.

6. RANGE CHANNEL AMPLIFIER

The range channel amplifier unit (Figs 85, 86) is located in the left upper corner of the main control board cabinet under the amplifier unit of the automatic tracking channel.

The range channel amplifier unit is designed for additional amplification of signals to a value ensuring the normal operation of the range indicator unit, plan-position indicator unit and automatic range finder.

The range channel amplifier unit (Fig.87, See Album) consists of one I.F. amplifier stage, a detector and three video amplifier stages. The unit chassis carries +300-volt and -150-volt rectifiers as well.

The input of the range channel amplifier unit is fed with I.F. voltage from the output of the eighth I.F. amplifier stage of the range channel (V1-11) located in the automatic tracking channel amplifier unit. The first I.F. amplifier stage of the unit is based on a resonant amplifier

/with an

with an oscillatory circuit in the grid circuit. The cathode circuit of valve V2-1 includes variable resistor R2-3 by means of which the range channel amplification is regulated.

Resistor R2-3 is part of the divider in the circuit of the rectifier voltage of +300 V. The slider shaft of the resistor is brought out to the unit front panel and marked NOISE LEVEL SETTING. Resistor R2-1 is the load of the output cable and its value equals the cable characteristic impedance. The application of this resistor is similar to that of resistor R1-1 of the automatic tracking channel amplifier unit.

The signal voltage amplified by an I.F. amplifier stage (V2-1) is applied to the detector, i.e. to the right-hand diode of valve V2-2 (6H6S). The overall intermediate frequency amplification of the range circuit (from the input of the intermediate frequency pre-amplifier to the tenth stage of the range channel intermediate frequency amplifier), is about 75,000.

The load of detector V2-2 is resistor R2-7. Choke L2-3 and capacitor C2-7 constitute an intermediate frequency filter which prevents penetration of I.F. voltage to the video amplifier input.

The first and second stages of the video amplifier (V2-3 and V2-4) employ valves of the 6Z4 type connected as triodes, which ensures uniform amplitude characteristic.

The grid of the first video amplifier stage (V2-3) is fed with positive pulses from resistor R2-7. Therefore, the initial negative bias from divider R2-9, R2-10, connected into the -105-volt rectifier, is applied to the control grid of this valve to cancel out amplitude distortions caused by grid currents.

For high-frequency compensation the plate circuit of the first stage contains choke L2-4 connected in series with resistor R2-12.

The negative pulse is applied to the grid of valve V2-4 and because of this it is not supplied with additional negative bias.

.../Resistor R2-17

Resistor R2-17 and capacitor C2-11 are correcting elements improving frequency characteristic of the stage and, consequently, of the entire video amplifier. In the low-frequency region the capacitive reactance of capacitor C2-11 becomes greater than resistance value of R2-17. As a result the negative feedback reduces amplification of the stage in the low-frequency region, which is equivalent to the high-frequency rise. The stage operates without the initial negative bias, therefore, the bias on the valve grid is determined by an average noise level. Should the noise arise the operating point of the stage characteristic is shifted to the right due to appearance of additional bias voltage caused by the grid current across resistor R2-16 whose value is approximately 470 kilohms. In this case the amplification factor of the stage decreases and the previous noise level is preserved on the tubes. Thus, approximately constant noise level is kept on the tube screens, which facilitates observation of weak signals.

The plate load of the second video amplifier stage is resistor R2-15. Resistors R2-39, R2-14 and capacitor C2-12 constitute a decoupling filter in the supply circuit.

The third stage employs valve 6P3S (V2-5). The bias to its control grid is fed by the -105-volt rectifier from divider R2-19, R2-20. The plate load consists of resistors R2-26, R2-25, R2-24, R2-23, R2-21 and R2-22 whose total resistance value is 1.5 kilohms. The negative voltage pulses of 120 V amplitude are conducted to the range indicator unit (to connector Zw3-4) from the plate load of this stage through connector Zw2-3.

From connector Zw2-2 the positive pulses are furnished to the range finder unit (to connector Zw7-4). In this case the pulses are taken from resistor R2-30 in the valve cathode circuit.

The plan-position indicator is supplied with the output voltage through the divider (resistors R2-28, R2-29). The negative pulses of 12 V amplitude

.../taken from

taken from the part of the divider (R2-29) are applied to the plan-position indicator through connector Zw2-4 (pin 5).

The +300-volt rectifier employs two kenotrons of the 5C4S type (V2-7 and V2-3). Capacitors C2-20, C2-19 and choke Dl2-1 constitute a mid-shunt filter in the rectifier circuit. Connected in series with the choke are two wire-wound resistors R2-33 and R2-34, one of them being connected as a potentiometer and serves to regulate the rectifier output voltage during the unit tuning.

The -105-volt rectifier utilizes kenotron of the 5C4S (V2-9). The voltage of -105 V is stabilized by stabilovolt SG3S (V2-10).

The neon lamps N2-11 and N2-12 serve for checking the +300 V and the -105 V rectified voltages. They are located on the front panel of the assembly (Fig.85).

Chapter 5

RANGE MEASURING SYSTEM

1. GENERAL

The range measuring system is designed to measure the target range continuously and accurately in the manual or automatic range tracking mode of operation and to synchronize the operation of the transmitter, receiver and the plan-position indicator system.

The range measuring system (Fig.88) consists of the following components: a range unit, a range and very narrow gate indicator, a range mechanism and an automatic range finder.

The range measuring system is fed from the power pack of the range measuring system and plan-position indicator and from the power pack of the range measuring system.

The range unit synchronizes the operation of the transmitter, the receiver, the range and very narrow gate indicator unit, the automatic range

finder and the plan-position indicator unit. For this purpose the range unit generates sweep voltages for the fine and coarse range tubes, trigger pulses to trigger the transmitter and start the plan-position indicator sweeps, voltage pulses to brighten the sweeps of the coarse range tube, pulses to form the plan-position indicator range markers, pulses gating the sweep trace on the fine range tube and the plan-position indicator tube and forming the electronic marker on the coarse range tube.

The range and very narrow gate indicator is designed for visual observation of the signals reflected from the targets. Besides, the unit accommodates the final stages of the very narrow gate forming circuit. The very narrow gate makes the receiver automatic tracking channel conducting and triggers the gate forming circuit in the automatic range finder unit and the circuit for forming an electronic marker on the fine range tube.

Short very narrow gate pulses, making the receiver automatic tracking channel conducting at the instant the signal reflected from the selected target arrives, makes possible the tracking of the selected target automatically in angular coordinates despite the presence of other targets located at various ranges in the zone of the antenna beam coverage.

The range mechanism unit is designed for mechanical control of the devices for tracking the target in range (the phase shifter and strobe decade potentiometer) with range data transmission by means of the coarse and fine selsyns.

The unit incorporates the stages of the very narrow gate forming circuit. When rotating the range knob the phase of the voltage, forming the very narrow gate, reverses relative to the phase of the crystal generator voltage, which alters the start of the very narrow gate and the position of the fine range tube electronic marker relative to the range zero mark.

The automatic range finder unit provides continuous tracking of the target in range. For this purpose the unit produces a 50 c.p.s. control

.../voltage which

voltage which is applied to the automatic tracking motor in the range mechanism unit.

The value and phase of the control voltage are such that the automatic tracking motor (rotating the shaft of the range mechanism and the shaft of the phase shifter) ensures continuous alignment of the electronic marker with the signal from the target being tracked.

2. OPERATING PRINCIPLE OF RANGE MEASURING SYSTEM

A functional diagram of the range measuring system is presented in Fig. 89.

Formation of Sweeps on Fine and Coarse Range Indicators

Circular sweeps on the fine and coarse range indicators are formed when the electron flow is acted upon by sine-wave voltages equal in amplitude and shifted in phase by 90°. The indicator sensitivity for horizontal and vertical deflecting plates to which sweep voltages shifted in phase are applied, is different, therefore in practice the amplitudes of the given voltages are also different.

The voltage applied to the vertical deflecting plates of the indicator (Fig.90) causes the indicator electron beam and, consequently, the bright spot on the screen to deflect up and down from the centre by a value proportional to the instantaneous value of the voltage.

The voltage applied to the horizontal deflecting plates of the indicator deflects the bright spot to the left and right from the centre. During simultaneous action of two voltages applied to the indicator deflecting plates the bright spot moves both in horizontal and vertical planes successively passing points 0, 1, 2, 3, etc. on the screen, i.e. moves in a circumference.

The time of one revolution of the bright spot equals the cycle of the sweep voltage applied to the plates.

.../To obtain

To obtain the circular sweep on the fine range indicator the range unit and the range indicator unit produce two sine-wave voltages of 74.955 Kc/s, shifted in phase by 90°.

The voltage of 74.955 Kc/s (approximately 75 Kc/s) is produced by the crystal-controlled oscillator. The oscillation frequency of the crystal oscillator is somewhat lower than 75 Kc/s, because the propagation velocity of radio waves is not 300,000 km/sec. but a bit lower than this value.

The oscillator voltage period, which is a precise time reference, makes up 13.3 microsec. and equals the time required for the electromagnetic siganl to make a round trip between the transmitter and the target that are two kilometres apart. Therefore, the length of the sweep circumference of the fine range indicator corresponds to the range of 2 km.

To create a circular sweep on the coarse range indicator two sine-wave voltages of 3.75 Kc/s are required. The frequency of these voltages is 20 times as small as that of the crystal oscillator and consequently the time during which the sweep describes a circle on the screen of the coarse range indicator corresponds to the range of 40 km.

The crystal oscillator voltage is applied to the frequency division circuit which generates voltages 5, 20 and 40 times lower than the frequency of the crystal oscillator, i.e. approximately 15, 3.75 and 1.875 Kc/s. The frequency is divided by multivibrators.

The first multivibrator is synchronized by the voltage of the crystal oscillator. This voltage is previously converted into a pulse voltage of the same frequency in the trigger pulse oscillator stage. The circuit is designed in such a way that the first multivibrator, which will be henceforth referred to as multivibrator 15 Kc/s, generates a pulse voltage whose frequency is five times as low as that of the crystal oscillator.

The voltage of multivibrator 15 Kc/s synchronizes in turn the next multivibrator that divides frequency by four. Thus the voltage of the

.../second multivibrator

second multivibrator has a frequency 20 times as low as that of the crystal oscillator, i.e. 3.748 Kc/s. This multivibrator is called multivibrator 3.75 Kc/s.

The output voltage of multivibrator 3.75 Kc/s of approximately square-wave form is applied to the resonance amplifier whose load is a phase shifting transformer. This transformer produces two voltages of 3.75 Kc/s equal in amplitude and 90° out of phase in relation to each other. These voltages are applied through resonance transformer to two pairs of deflecting plates of the coarse range indicator. The form of output voltages of resonance transformers approaches the sine-wave form and therefore, creates a circular sweep on the indicator screen; the duration of one sweep revolution corresponds to one period of the sine-wave voltage and equals 266 microsec.

The signals reflected from the target are furnished from the output of the receiver range channel amplifier to central deflecting electrode of both range indicators and form radial pips on the sweeps, i.e. target markers.

Trigger Pulse Formation

The target range can be measured accurately only when the display of the echo signals remains stationary on the sweeps of the range indicators or when the movement of the target signal on the indicator screens is caused only by the displacement of the target in space. Therefore, the moment the transmitter fires the pulse should always coincide with the moment the electron beam passes the definite point on the sweep which will correspond to the range scale zero.

The moment the electron beam passes the mentioned point is determined by the phase of voltages creating the sweep. This phase always corresponds to the definite phase of the crystal oscillator voltage. This is obtained by the use of the trigger oscillator pulses of 74.955 Kc/s for formation

.../of trigger

of trigger pulses. The trigger pulses (of a frequency of 1.875 Kc/sec) make the station transmitter operative.

The trigger pulses of the required frequency are formed in the selector to which the trigger oscillator pulses of 75 Kc/s and strobe pulses are furnished. The strobe pulses are formed by the circuit composed of multivibrator 1.875 Kc/s, a limiter, a gating delay and trigger pulse electron relay, a strobe pulse width electron relay and a cathode follower.

The multivibrator 1.875 Kc/s synchronized by the voltage from the multivibrator 3.75 Kc/s, produces an A.C. voltage of approximately square-wave form whose frequency is 40 times as low as the crystal oscillator frequency. This voltage is used for triggering the gating delay and trigger pulse electron relay in which the pulse of regulated duration is formed.

The trailing edge of the pulse of regulated duration triggers the strobe pulse width relay which produces strobe square-wave pulses of 9 microsec. duration. These pulses are applied through the cathode follower to the trigger selector which passes only those pulses of the trigger oscillator that are timed with the strobe pulses.

By changing the value of the strobe pulse delay within the range of 0 to 80 microsec. the strobe pulse may be timed with any of the five trigger pulses coming in succession with 13.3 microsec. pulse interval. In this case the trigger pulse is formed at the trigger selector output, corresponding to the range zero and used to trigger the transmitter and the plan-position indicator unit.

Formation of Gating Pulses for the Brightening of the Sweep of Coarse Range Indicator

Between two trigger pulses adjacent in time the electron beam of the coarse range indicator makes two complete revolutions. As a result an error in target range may arise. For instance, if the distance between the

.../station and

station and two targets is 10 and 50 km. respectively, the target echo signals on the screen of the coarse range indicator will be observed at the same point on the sweep corresponding to 10 km.

To avoid errors when determining the range the sweep of the coarse range indicator is brightened only for the period of the first revolution of the electron beam after every trigger pulse. For the remainder of the time in which the electron beam performs a second revolution, the tube is not brightened and targets at a distance of 40 km. or more are invisible on the screen.

The brightening voltage gating pulses furnished to the control electrode of the coarse range indicator are formed with the help of the gate width electron relay, generating positive square-wave pulses of regulated duration (from 0 to 270 microsec.).

The gate width electron relay is triggered by the gating delay and trigger pulse electron relay, and therefore, the beginning of the coarse range indicator gating coincides with that of the strobe pulse and leads the beginning of trigger pulses by approximately half of the strobe pulse duration (600 m. on the scale). Thus the radiated pulse can always be seen on the screen of the coarse range indicator.

Strobe Pulse Formation

To determine the range more accurately the range measuring system is provided with a fine range indicator whose screen displays any two-kilometre section of the coarse range indicator sweep on a larger scale.

For a period between two successive pulses fired by the transmitter the electron beam of the fine range indicator should make 40 revolutions. Therefore, the displays of the target echoes obtained on various revolutions of the sweep are superimposed, thereby making it impossible for the operator to determine on which revolution of the sweep after the transmitter pulse one or another echo is displayed.

.../To avoid

To avoid this it is necessary that only that section of the sweep be brightened on the fine range indicator which corresponds to the sweep section selected on the coarse range indicator.

The selected sweep section of the fine range indicator is brightened by the strobe pulse applied to the control electrode of the fine range indicator. In addition, the strobe pulse is used as an electronic marker on the coarse range indicator.

By matching the electronic marker (strobe pulse) of the coarse range indicator with the echo signal it is possible to determine the target range, i.e. to measure the time between the moment the transmitter pulse is fired and the moment the signal reflected from the target arrives. The time delay of the strobe pulse relative to the trigger pulse corresponds to the slant range of the matched target. This range is read on the scale of the range mechanism.

The strobe pulse forming circuit utilizes four valves of the strobe pulse delay circuit, a strobe width electron relay and a cathode follower.

The strobe pulse is set on the sweep by means of the range handwheel which is mechanically coupled to the shaft of the strobe pulse delay potentiometer. Taken from the potentiometer slider is a D.C. voltage which changes linearly when rotating the handwheel and is applied to the strobe pulse delay circuit.

The strobe pulse delay circuit is composed of a control valve, a trigger valve, a limiter and a quenching valve. The trigger pulses are applied to the delay circuit from multivibrator 1.875 Kc/s. The saw-tooth oscillator (phantastron) provided in the circuit produces linearly decreasing saw-tooth voltage of 1.875 Kc/s. At the moment the amplitude of the saw-tooth voltage equals the value of voltage fed from the slider of the strobe delay potentiometer, the strobe delay circuit triggers the strobe width electron relay. The saw-tooth pulse duration ensures the strobe delay from 0 to 40 km.

.../The strobe

The strobe width electron relay squares positive and negative strobe pulses of regulated duration. Positive strobe pulses are applied through the cathode follower to the selector of the very narrow gate circuit, to the control grid of the fine range tube for gating the sweep and thence to the plan-position indicator tube for gating the corresponding range section. The strobe pulses of negative polarity are applied to the cathode of the coarse range tube to produce an electronic marker in the form of a bright spot on the sweep trace.

Formation of Very Narrow Gate and Electronic Marker of Fine Range Indicator

Very narrow gate pulses of 0.3 microsec. duration serve to make the receiver automatic tracking channel conducting when the signal reflected from the selected target arrives to trigger the strobe forming circuit in the automatic range finder unit and to trigger the electronic marker forming circuit. When the very narrow gate has the above duration, the range resolution is practically about 125 m., i.e. the antenna positioning system will ensure accurate tracking of either of the two targets which differ in range by not greater than 125 m. (at manual range tracking).

Used as a reference voltage to obtain the very narrow gate is the sine-wave voltage of the crystal oscillator.

The voltage of 75 Kc/s is applied to the input amplifier in the range mechanism unit and then to the cathode follower and the phase shifter. The phase shifter produces a voltage whose phase changes linearly with rotation of the phase shifter rotor. The latter is mechanically coupled to the range handwheel. The voltage shifted in phase is amplified and is applied to the clipper-amplifier in the range indicator unit.

The voltage at the clipper-amplifier output has an approximately square-wave form. The clipper-amplifier voltage is used for shocking the oscillatory circuit in the selector grid circuit into excitation. The control grid of the selector produces positive and negative pulses of

 .../75 Kc/s. Simultaneously

75 Kc/s. Simultaneously the selector suppressor grid is fed with positive strobe pulses. When the strobe pulse is timed with one of positive pulses of 75 Kc/s the selector produces the pulse triggering the very narrow gate blocking oscillator.

The very narrow gate blocking oscillator generates narrow back-to-back saw-tooth pulses of positive and negative polarity. The positive pulse is furnished to the receiver and the automatic range finder, the negative one - to the electronic marker forming circuit which includes two blocking oscillators and a delay line for 0.4 microsec.

Connected into the first cathode circuit of the blocking oscillator is the delay line for 0.4 microsec. opened at the end. The very narrow gate pulse triggers the first blocking oscillator and a positive pulse is developed across the cathode resistor, which is reflected from the end of the open line and in 0.8 microsec. appears on the cathode resistor. From the cathode load two pulses shifted in time by 0.8 microsec., are applied to the second blocking oscillator of the electronic marker. In the cathode circuit of the second blocking oscillator two back-to-back saw-tooth pulses are produced which are supplied in succession to the cathode of the fine range indicator forming two gaps on the sweep trace, i.e. the electronic marker.

The range is determined accurately by setting the electronic marker of the fine range indicator symmetrically relative to the echo signal so that the end of the first and the beginning of the second mark of the electronic marker are equally spaced from the sweep line, the target range may be read on the scales of the range mechanism unit.

Principle of Automatic Range Tracking

A simplified functional diagram of the automatic range tracking follow-up system is shown in Fig. 91.

The automatic range tracking circuit ensures continuous automatic tracking of a target at the distance of 0.5 to 35 km. from the station.

.../The automatic

The automatic range finder allows the tracking of targets moving at a speed of 0 to 250 m/sec.

Provision is made in the mechanism for manual target tracking in range with the help of the manual tracking handwheel. The target is tracked manually when automatic target tracking is impossible.

To track the target automatically in angular coordinates the receiver automatic tracking channel should be made conducting at the instant the signal returned from the moving target arrives. The moment the very narrow gate appears is determined by the position obtained by the shaft of the phase shifter and the shaft of the strobe potentiometer, i.e. by the position of the range mechanism. Thus, the follow-up system must automatically rotate the range mechanism at the speed the target slant range changes.

The very narrow gate pulse triggers the split gate forming circuit through a delay line of 0.17 microsec.

Two square-wave pulses equal in amplitude and duration are obtained at the output of the gate forming stages, the end of the first pulse being matched with the beginning of the second. Thus two pulses are accurately aligned with the very narrow gate pulse. Pulses of 0.6 microsec. duration ensure the range resolution of 200 m.

The delay value (0.17 microsec.) is selected so that at the instant the pulses on the discriminator symmetrically divide the video signal, the very narrow gate passes the signals from the target being tracked through the receiver automatic tracking channel. In this case the electronic marker on the fine range indicator is set symmetrically relative to the target echo.

The video signals from the receiver range channel are amplified by the video amplifier in the automatic range finder and are furnished to the error signal time discriminator. The discriminator separates the target echo from other signals and halves it.

.../The separated

The separated pulses are converted in the error signal discriminator in D.C. voltages and the difference of "areas" of the separated pulses determines the value of the error signal. Both separating signals are produced during transmission of every pulse.

The error signal is amplified by the D.C. amplifier and from the cathode follower is applied to the converter. Taken from the converter transformer secondary winding is an A.C. voltage of 50 c.p.s. modulated by the error voltage.

The error voltage of 50 c.p.s. is amplified by the resonance amplifier whose amplification factor is automatically regulated by changing the bias on the control grid. The bias voltage is developed by detecting (in the AGC detector stage) the video signal applied from the automatic tracking unit.

The amplitude of the video signals depends upon the change on the target range. A decrease in the video signal amplitude (at the same error value between the split gate and the signal) causes a decrease of the error signal, as the difference of the separated pulse "areas" decreases.

The AGC in the D.C. amplifier ensures constancy of the common amplification factor of the automatic range finder tracking system over the entire band of target tracking in range.

The error voltage of 50 c.p.s. is applied to the control winding of the automatic tracking motor in the range mechanism unit. Depending on the value and phase of the voltage the motor drives the range mechanism, following up the error signal and ensuring continuous symmetrical alignment of the electronic marker with the target echo signal on the fine range tube.

3. RANGE UNIT

A key diagram of the range unit is presented in Fig.92 (See Album). The front panel and the unit top view are shown in Figs 93 and 94.

.../The voltage

The voltage wave forms in separate stages of the range unit and their time relations are shown in Fig.95.

Crystal Oscillator

The crystal oscillator is designed to obtain a sine-wave voltage of 75 Kc/s (74.955 Kc/s more precisely) having high stability in frequency.

The application of the crystal makes it possible to ensure constancy of the frequency of the voltage produced by the oscillator within $\pm$ 4 c.p.s. at temperature variations from -40 to +60°C. In this case the range measuring errors caused by the oscillator frequency drift do not exceed $\pm$2 m. (at a distance of up to 40 km.).

The crystal oscillator is based on an electron-coupled circuit employing valve V8-1 (6K3) which functions as a self-excited oscillator and a sine-wave voltage amplifier. In the oscillator circuit the valve screen grid functions as the plate. Used as negative feedback voltage is a voltage developed across choke L8-1 located in the cathode circuit. The plate circuit of the valve is used to amplify the voltage of 75 Kc/s.

The range unit is provided with two crystals K8-1 and K8-2. One of them is an operating crystal, the other is a spare one. The crystals are switched over by setting the spare crystal in place of the operating one.

When sustained oscillations of 75 kc/s are established in the circuits of the control and screen grids of valve V8-1 the plate current of the valve will contain the D.C. component of the same frequency. Connected into the plate circuit of the valve is the primary circuit of phase shifting transformer Tr8-1. The circuit of the transformer contains two resonant circuits and two coupling coils.

The phase shifting transformer produces two sine-wave voltages, shifted in phase by 90° with respect to each other, which are taken from the coupling coils.

These two voltages are fed out to the range and very narrow gate indicator, thence they are applied through resonant step-down transformers

to two pairs of deflecting plates of the fine range indicator to form the circular sweep.

The primary and secondary circuits of transformer Tr8-1 are tuned to the frequency of 75 Kc/s and have weak coupling between each other. The weak coupling is selected to diminish the influence of one circuit on the resonance curve of the other circuit.

The primary circuit coil is tightly coupled with its coupling coil. These two coils have a common alsifer core with a shaft brought out on top of the transformer housing. The secondary circuit coil is also tightly coupled with its coupling coil and the shaft of their common alsifer core is brought out through the base of the transformer housing.

The A.C. component of current I_1 flowing through coil L8-2 of the primary circuit creates a variable magnetic field due to which alternating E.M.F. E_2, lagging in phase by 90° from current I_1, is induced in coil L8-3 of the secondary circuit (Fig.96).

Electromotive force E_2 produces current I_2 in the secondary circuit which in case of resonance tuning of the secondary circuit is in phase with electromotive force E_2. Thus with the tuned secondary circuit the currents of the primary and secondary circuits prove to be shifted in phase by 90° with respect to each other. These currents induce electromotive forces E_3 and E_4 in the coupling coils, which lag the currents by the same angle of 90°. Therefore, the electromotive forces in the coupling coils prove to be shifted in phase by 90° as well.

Provision is made in the crystal oscillator circuit for the following four regulations which ensure the correct form and diameter of the sweep on the fine range tube:

1. Resonance tuning of the primary circuit of the phase shifting transformer to the oscillator frequency. The tuning is carried out by the alsifer core with a shaft brought out to the top of the transformer housing and by variable capacitor C8-54 whose movable plate shaft is brought out

.../to the

to the front panel of the unit and is marked GENERATOR. With resonance tuning of the phase shifting transformer primary circuit maximum voltages are developed across the coupling coils and, consequently, the maximum diameter of the circular sweep on the fine range indicator is obtained.

2. Regulation of the diameter of the fine range indicator sweep which is done by changing the voltage on the screen grid of valve V8-1. The change of this voltage causes the change of the amplitude of the crystal oscillator A.C. voltage and therefore the amplitude of the voltages taken from the coupling coils of the phase shifting transformer. The screen grid voltage is regulated by variable resistor R8-36 whose shaft is brought out to the right-hand part of the unit front panel and is marked DIAMETER.

3. Tuning of the secondary circuit of the phase shifting transformer to obtain the required phase shift between the sweep voltages. This tuning is carried out by the alsifer core with a shaft brought out to the bottom of the transformer housing and by variable capacitor C8-58 whose movable plate shaft is brought out to the right-hand part of the unit front panel and marked PHASE. At accurate tuning of the transformer secondary circuit to the crystal oscillator frequency the phase shift between the two sweep voltages becomes equal to 90°. If in this case the amplitudes of both voltages are the same the sweep assumes the shape of correct circumference. When the secondary circuit is detuned the phase shift between the two sweep voltages differs from 90° and the sweep assumes the shape of an ellipse whose axes occupy inclined position relative to the planes of the tube deflecting plates.

4. Balancing the amplitudes of the two sweep voltages, which is effected by variable resistor R8-38. Its shaft is brought out to the right-hand part of the unit front panel and is marked BALANCE.

Tuning with the aid of the alsifer cores is usually done in the manufacturing plant; it should not be carried out when the set is in use,

.../unless it

unless it is impossible to arrive at correct tuning by using controls brought out to the front panel of the unit (for instance due to considerable change in the climatic conditions).

If the phase shift between the two sweep voltages is 90° though the amplitudes are not equal, the sweep trace assumes the shape of an ellipse whose axes are parallel to the planes of the tube deflecting plates.

Variable resistor R8-38 makes it possible to change the quality factor of the tuned secondary circuit and thereby change the amplitude of the voltage taken from the appropriate coupling coil.

It should be borne in mind that the regulation of the phase shift between the two sweep voltages slightly changes the relationship of these voltages, while the regulation of the amplitude of the voltage taken from the coupling coil slightly changes the phase shift between the two sweep voltages. Therefore when tuning the unit it is necessary sometimes to perform alternately both last regulation procedures (by potentiometers PHASE and BALANCE) until the sweep assumes the shape of correct circumference on the screen of the tube.

Trigger Pulse Oscillator

The trigger pulse oscillator employing the right-hand triode of valve V8-6 (6N8S) is a buffer stage placed between the crystal oscillator and succeeding stages which serves at the same time to convert the sine-wave voltage of 75 Kc/s into positive voltage pulses of the same frequency.

The sine-wave voltage of the crystal oscillator (Fig.95, a) is applied to the grid of the right-hand triode of valve V8-6 through coupling capacitor C8-21. As the voltage rises on the grid from the plate current cut-off level to its maximum value the stage operates as a cathode follower and the voltage on its cathode increases approximately sinusoidally. This results in charging of capacitor C8-20. When the voltage on the valve grid begins decreasing, the rate of the voltage decrease on the cathode

.../proves to

proves to be limited by the rate at which capacitor C8-20 discharges through resistor R8-25. The time constant of this circuit is about 5 microsec., which results in considerably slower voltage drop on the cathode as compared with the grid. This brings about a rapid cut-off of the valve, after which the voltage on its cathode drops exponentially until the voltage rise on the grid makes the valve conducting again (Fig.97).

With the voltage on the grid approximating +105 V relative to earth, the grid potential equalizes the cathode potential and the grid current appears in the valve which rapidly charges coupling capacitor C8-21.

The time constant of the discharge circuit of this capacitor (C8-21, R8-26) is very large (110,000 microsec.). As a result an automatic negative bias voltage is developed on the grid of the right-hand triode of valve V8-6. This voltage is approximately equal to the excess of the crystal oscillator voltage amplitude above the level of 105 V. The amplitude value of the crystal oscillator voltage is about 115 to 120 V, therefore the negative bias voltage on the valve grid relative to earth amounts to 10 - 15 V.

Positive voltage pulses are applied from the valve cathode to the control grid of valve V8-13 of the trigger pulse selector. These pulses are also used to synchronize multivibrator 15 Kc/s.

Frequency Dividers

The frequency of 75 Kc/s is divided by the circuit composed of three multivibrators in which the oscillation frequency is decreased five, four and two times, respectively.

The first multivibrator producing the voltage of 15 Kc/s employs double triode V8-2 (6N9S). The voltage of trigger pulse oscillator causes the multivibrator to be synchronized and produce an A.C. voltage whose frequency is five times as low as that of the synchronizing pulses, i.e. a frequency of 15 Kc/s (Fig.95, b). Thus, the multivibrator serves as a frequency divider.

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.../To ensure

To ensure reliable synchronizing by the trigger pulse the multivibrator circuit parameters are selected so that its natural frequency is slightly less than 15 Kc/s.

Fig.98 is a representation of charts of voltages acting in multivibrator 15 Kc/s (V8-2), the solid lines belonging to the mode of synchronizing oscillations, and the dashed ones to the multivibrator free oscillations in the absence of synchronizing pulses.

Free oscillations are generated and maintained in the following way:

When switching on the plate voltage, plate currents flow through both triodes of valve V8-2; coupling capacitor C8-5 is charged to the value of the right-hand triode plate voltage, while coupling capacitors C8-6, C8-7 to the value of the left-hand triode plate voltage.

It may be assumed that at the initial moment the currents passing through both triodes of the valve and, consequently, the voltages across the coupling capacitors are equal since load resistors R8-5A and R8-5B having the same value are connected into the plate circuits of both triodes. But such balance is not stable in this system.

Any accidental change of the current flowing for instance, through the left-hand triode causes the voltage to change on its plate. Thus, for instance, a decrease of the left-hand triode current involves a voltage rise on its plate. This voltage rise is conducted through the coupling capacitor to the grid of the right-hand triode and causes an increase of the current flowing through it. The rise of the right-hand triode plate current is accompanied by a decrease of its plate voltage due to an increased voltage drop across load resistor R8-5B. This voltage drop is conducted from the right-hand triode plate to the grid of the left-hand triode through coupling capacitor C8-5 and causes a further decrease of its plate current.

Thus, any accidental, even the smallest, decrease of the plate current of the left-hand triode gives rise to a process going on in an avalanche-

like manner, which brings about a complete cutting off of this triode. In this case the grid voltage of the left-hand triode drops appreciably lower than the cut-off level. Simultaneously coupling capacitor C8-5 begins to slowly discharge through the right-hand conducting triode of the valve through resistor R8-4. As the capacitor discharges the grid voltage of the left-hand triode gradually increases. At the moment it reaches the cut-off level a plate current appears in the left-hand triode and the voltage on its plate decreases. This voltage decrease conducted through the coupling capacitor to the grid of the right-hand triode causes a decrease of its plate current and, consequently, an increase of the plate voltage which in turn is applied through coupling capacitor C8-5 to the grid of the left-hand triode. Thus, another avalanche-like process of the multivibrator turnover is started, which results in the conducting left-hand triode, and cut-off right-hand one.

The system remains in this state until the grid voltage of the right-hand triode, which is gradually increasing during the discharge of the coupling capacitor through the left-hand triode and resistor R8-7, reaches the cut-off level. At this moment the right-hand triode is made conducting, whereas the left-hand triode is cut off, i.e. another turnover of the circuit takes place. Further the process is repeated.

Thus the multivibrator generates oscillations whose frequency is determined in the main by time constants of the grid circuits, i.e. the circuits formed by the coupling capacitors and grid leak resistors. This frequency is called the multivibrator natural frequency.

In order to obtain the multivibrator oscillations with a frequency five times as low as that of the crystal oscillator voltage, the multivibrator is synchronized by positive voltage pulses from the trigger pulse oscillator. These voltage pulses are fed out through a differentiating circuit formed by capacitor C8-4 and A.C. resistance between the plate of the left-hand triode and earth. The value of this resistance at the moment of

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.../synchronization equals

synchronization equals the equivalent resistance of the circuit consisting of a parallel combination of three resistors: the differential resistance of the left-hand triode (R_i) and the resistance of the grid - cathode section of the right-hand triode, as long as the coupling capacitance is considerably greater than the capacitance of C8-4.

The time constant of the given differentiating circuit makes up fractions of a microsecond, i.e. considerably shorter than the duration of the pulses produced by the trigger pulse oscillator (13.3 microsec.). Therefore, the plate of the left-hand triode of valve V8-2 is fed with rather short positive voltage pulses, small in amplitude (Fig.98, b), which are timed with the most steep part of the positive leading edge of each pulse supplied from valve V8-6 (Fig.98, a). Considerably more flat negative voltage drops on the cathode of the trigger oscillator valve do not practically produce noticeable negative voltage pulses at the output of the differentiating circuit, i.e. on the plate of the left-hand triode of valve V8-2.

Through the coupling capacitor the short positive synchronizing voltage pulses are furnished from the plate of the left-hand to the grid of the right-hand triode of valve V8-2 (Fig.98, c, d). Those pulses which arrive when positive or zero voltage is acting on the grid of the right-hand triode (pulses 0, 3, 4, 5 in Fig.98) cause noticeable charge of coupling capacitors C8-6 and C8-7 on account of the grid current of the right-hand triode. As a result at the moment of a pulse end the grid voltage of the right-hand triode drops considerably below the value which was at the beginning of the pulse (Fig.98, d). According to it the amplified negative pulse on the plate of the right-hand triode will end at more high voltage level as compared with that from which it has started (Fig.98, b).

These negative pulses are furnished through coupling capacitor C8-5 from the plate of the right-hand triode to the grid of the left-hand triode.

.../As a

As a result the grid voltage of the left-hand triode by the moment the pulse ends proves to be considerably higher than the value it would be equal to in the absence of synchronizing pulses (Fig.98, f).

With properly selected parameters of the multivibrator circuit the positive voltage drop at the end of every fifth negative pulse, furnished from the plate of the right-hand triode to the grid of the left-hand triode, causes the appearance of the plate current in the left-hand triode and an associated avalanche-like process of complete opening of the left-hand triode and cutting-off of the right-hand triode. In this case a steep negative voltage drop, large in amplitude is developed on the plate of the left-hand triode.

Thus the multivibrator produces oscillations with a frequency exactly five times as low as the frequency of the synchronising pulses, i.e. the frequency of the crystal oscillator.

For stable synchronous operation of the multivibrator with the desired frequency the parameters of its circuit are selected so that the cycle of the multivibrator natural oscillations is somewhat in excess of the five cycles of the crystal oscillator oscillations. The frequency of the multivibrator natural oscillations is regulated by variable capacitor C8-6 whose shaft is brought out to the front panel of the range unit and is marked 15 Kc/s.

In the multivibrator circuit parameters are varied within small limits the moment the positive voltage begins dropping on the plate of the left-hand triode (i.e. the moment the right-hand triode is triggered) changes in relation to the synchronizing pulses, while the moment when the negative voltage drop begins to be developed on the plate (i.e. the moment the right-hand triode is cut off) is always coincident with the moment of action of every fifth synchronizing pulse. So during the operation of the given multivibrator it is the negative voltage drops on the plate of the left-hand triode that are strictly synchronized. They are used in the circuit

.../to synchronize

to synchronize the multivibrator 3.75 Kc/s and finally determine the starting moment of successive multivibrators (frequency dividers) as well as to delay electron relay.

From the plate of the left-hand triode of valve V8-2 the pulses (Fig.98, c) are furnished to next frequency division stage, i.e. the multivibrator 3.75 Kc/s employing valve V8-3 through the differentiating circuit formed by capacitor C8-8 and equivalent A.C. resistance between the plate of the left-hand triode of valve V8-3 and earth. Due to a small time constant of the circuit (about 0.1 microsec.) the plate of the left-hand triode of valve V8-3 is supplied only with very short negative voltage pulses of small amplitude produced at the moment the negative voltage drops occur at the output of the differentiating circuit (Fig.99, a, b).

Much more flat positive voltage drops on the plate of the left-hand triode of valve V8-2 do not practically produce positive voltage pulses at the output of the differentiating circuit.

From the plate of the left-hand triode of valve V8-3 short synchronizing pulses are furnished through coupling capacitor C8-10 to the grid of the right-hand triode (Fig.99, c, d). The pulses that are applied to the grid of the right-hand triode when it is triggered (pulses 0, 3, 4 in Fig.99, b) are amplified and as positive voltage pulses are furnished from its plate (Fig.99, e) to the grid of the left-hand triode (Fig.99, f).

The parameters of the circuit multivibrator are selected in such a manner, that the voltage on the grid of left-hand triode does not reach the cut-off level when acted on by the third synchronizing pulse. Only the fourth synchronizing pulse causes the grid voltage of the left-hand triode to exceed the cut-off level. In this case the circuit is turned over in an avalanche-like manner, which gives start to a steep negative voltage drop on the plate of the left-hand triode. Every four cycles of synchronizing voltage this process is repeated, etc.

.../Thus, the

Thus, the multivibrator produces oscillations with a frequency exactly four times as low as the oscillation frequency of the first multivibrator and 20 times as low as the frequency of the crystal oscillator (Fig.95, e). In this case the steep negative voltage drops on the plate of the left-hand triode V8-3 are timed with the moment of action of every twentieth synchronizing pulse coming to the first multivibrator, i.e. with every twentieth voltage pulse at the trigger pulse oscillator output (the cathode of the right-hand triode of valve V8-6).

To make the synchronizing operation of the multivibrator stable it is necessary that the period of its natural oscillations should be slightly in excess of the four periods of the synchronizing voltage (dashed lines in Fig.99, c, d, e, f), i.e. that the frequency of multivibrator natural oscillations should be somewhat less than 3.75 Kc/s. The frequency of the multivibrator oscillations is regulated by variable resistor R8-12 whose shaft is brought out to the front panel of the unit and is marked "3.75 Kc/s".

The voltage from the plate of the left-hand triode of valve V8-3 is used to synchronize the third multivibrator (multivibrator 1.875 Kc/s). In addition, this voltage is fed out to the amplifier 3.75 Kc/s through coupling capacitor C8-14.

The multivibrator 1.875 Kc/s employing valve V8-4 (6N9S) generates a voltage of 1.875 Kc/s which resembles the voltage produced by the multivibrator 3.75 Kc/s. This multivibrator differs from the previous one only by the circuit parameters. The frequency of its natural oscillations is slightly less than 1.875 Kc/s. It is synchronized by every second synchronizing voltage pulse from the multivibrator 3.75 Kc/s.

The multivibrator natural oscillations are regulated by variable resistor R8-16, whose shaft is brought out to the front panel of the unit and is marked 1.875 Kc/s. The process of the multivibrator synchronization is similar to that taking place in the multivibrator 3.75 Kc/s.

.../Thus, with

Thus, with proper tuning of all three synchronized multivibrators an A.C. voltage is produced on the plate of the left-hand triode of valve V8-4 whose frequency is exactly 40 times as low as that of the crystal oscillator, the negative drops of this voltage being coincident with every fortieth voltage pulse produced by the trigger pulse oscillator.

The voltage from the plate of the left-hand triode of valve V8-4 is applied through coupling capacitor C8-31 to the grid of valve V8-12 (6Z4) which functions as a limiter, and through capacitor C8-29 to the pentode grid of valve V8-9 of the strobe delay circuit.

Amplifier 3.75 Kc/s

The amplifier 3.75 Kc/s employs valve V8-5 (6P3S). The plate load of the valve is the primary circuit of phase shifting transformer Tr8-2 tuned to the frequency of 3.75 Kc/s. Therefore, when the valve grid is fed with an A.C. voltage of an approximately square-wave from the multivibrator 3.75 Kc/s, A.C. voltages of the same frequency, whose wave-form is more close to the sine-wave, are developed across the phase shifting transformer windings. The autotransformer coupling of the primary circuit with the plate circuit of valve adds to improving the wave-form of the voltages acting across the transformer windings.

Phase shifting transformer Tr8-2 operates in the same way as the above phase shifting transformer Tr8-1 and produces two voltages which are used to form a circular sweep on the screen of the coarse range indicator.

To ensure a correct form of the sweep trace on the coarse range indicator the following controls are provided for:

1. Regulation of the sweep diameter by variable resistor R8-21. With the help of this variable resistor the voltage feeding the screen grid of valve V8-5 is varied. As a result the valve grid-plate transconductance changes and so does the amplitude of the plate current A.C. component. The shaft of the variable resistor is brought out to the left-hand part of the unit front panel and is marked DIAMETER.

2. Tuning of the secondary circuit of the phase shifting transformer by variable capacitor C8-65. The capacitor shaft is brought out to the left-hand part of the unit front panel and is marked PHASE.

3. Regulation of the amplitude of the voltage taken from the secondary circuit, which is made by variable resistor R8-19. The shaft of the variable resistor is brought out to the left-hand part of the unit front panel and is marked BALANCE.

The operation of the above controls does not differ from those of the fine range indicator sweep.

Besides, the primary and secondary circuits of the phase shifting transformer are tuned by the cores of the circuit coils. The core pins are located at the top and bottom on the transformer body. The tuning by these cores is usually done at the Manufacturing plant.

Limiter

The limiter employs valve V8-12 (6Z4). It is designed to generate an A.C. voltage with rather steep edges whose wave-form is nearly square.

The voltage that is the output of the multivibrator 1.875 Kc/s is applied from the plate of the left-hand triode of valve V8-4 to the valve control grid through coupling capacitor C8-31.

The distinctive feature of the limiting stage is a comparatively small time constant of the coupling circuit through which the input voltage is applied to the valve. The difference between the time constant of the coupling circuit (1000 microsec.) and the period of the multivibrator 1.875 Kc/s voltage (536 microsec.) makes it possible to obtain more correct square-wave form of the voltage on the valve plate.

If the time constant of the coupling circuit were considerably greater than the period of the input voltage the multivibrator plate voltage would be conducted to the valve grid almost undistorted, and practically (due to grid detection) the grid voltage chart would be located below the zero line and only its peaks would be slightly above zero.

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/Actually due

Actually due to comparatively small value of the coupling circuit time constant the grid voltage of the limiter valve noticeably differs in its wave-form from the output voltage of the multivibrator 1.875 Kc/s.

During the action of the negative voltage on the grid of valve V8-12 capacitor C8-31 is charged rather quickly. As a result the valve grid voltage rises more rapidly than the voltage on the multivibrator plate.

Thus, by the moment the right-hand triode of the multivibrator 1.875 Kc/s is cut off, the grid voltage of the limiter valve almost reaches the cut-off level, i.e. the limiter amplifies only the more steep initial section of the positive pulse edge of the multivibrator 1.875 Kc/s.

When the voltage on the limiter grid reaches zero level the grid current gives start to a rapid charge of capacitor C8-31. In this case as a result of a small value of the equivalent resistance of the grid - cathode section the grid voltage does not noticeably rise above zero.

At the moment when the negative voltage drops on the multivibrator the grid voltage of the valve sharply falls appreciably below the cut-off level.

Fig.100 shows the charts of the grid and plate voltages acting in the limiting stage. As seen from these charts the output voltage of the limiter valve has a wave-form which is much closer to the square-wave than the multivibrator voltage.

Resistor R8-53 connected into the valve cathode circuit serves to create current negative feedback which is weakened in the high-frequency region by capacitor C8-32, shunting resistor R8-53 (the time constant of this circuit makes up 150 microsec., i.e. considerably less than the period of the input voltage).

The application of the negative feedback with the rise of the high-frequency components adds to an increase of the voltage drop steepness at the limiter output.

It should be noted that the most steep voltage drops at the limiter output as is seen from the above analysis of the synchronized multivibrator operation, are always timed with the moment of action of every fortieth voltage pulse at the output of the trigger oscillator (the cathode of the right-hand triode of valve V8-6).

The limiter output voltage is applied through the differentiating circuit to the input of the gating delay and trigger pulse electron relay and its positive drops make this relay operative.

Trigger Pulse Formation

The trigger pulse forming circuit consists of a gating and trigger pulse delay electron relay (V8-7), a strobe-pulse width electron relay (V8-14), a cathode follower (V8-6A) and trigger pulse selector (V8-13).

The simplified diagram of the gating and trigger pulse delay electron relay is presented in Fig.101. The electron relay utilizes valve V8-7 (6N8S). The plate circuits of both triodes of the valve are provided with resistors R8-35 and R8-32 AB having approximately the same resistance value, whereas the common cathode circuit of the valve - with resistors R8-30 and R8-31.

The grid of the right-hand triode is connected through coupling capacitor C8-23, with the plate of the left-hand triode and through high-resistance resistor R8-34 to the +270-volt plate supply. The grid of the left-hand triode is supplied from the slider of variable resistor R8-27 through resistor R8-29 with a positive voltage whose magnitude can be regulated from 0 to +20 V.

The shaft of variable resistor R8-27 is brought out to the front panel of the unit and is marked TRIGGER PULSE DELAY.

The functioning of the delay electron relay is illustrated by the charts presented in Fig.102, a, b.

The positive square pulses from the limiter output are applied to the grid of the left-hand triode of valve V8-7 through the differentiating

circuit formed by capacitor C8-22 and resistor R8-29. The time constant of this circuit approximately equals 0.5 microsec. due to which the grid is fed in succession with only short spike pulses of positive and negative polarity which coincide with positive and negative drops of the limiter output voltage.

Before the positive voltage pulse is applied to the grid of the left-hand triode the right-hand triode of valve V8-7 is conducting. Due to large resistance of R8-34 in the grid circuit of the right-hand triode its grid potential is practically equal to the valve cathode potential. When the plate current of the right-hand triode flows, a voltage drop of about 40 V is developed across resistors R8-30 and R8-31, placed in the common cathode circuit of the valve.

Thus, if, for instance, the grid of the left-hand triode is fed from variable resistor R8-27 with a voltage of +16 V (relative to earth), the potential difference between the grid and the cathode equals -24 V, the triode is cut off and the voltage on its plate equals +270 V (relative to earth). In this case capacitor C8-23 proves to be charged to a voltage of +230 V.

This state of the circuit is stable and the circuit can remain in this state until the voltage pulse is applied to the grid of the left-hand triode of valve V8-7.

At the moment the positive voltage drop of the limiter occurs the grid of the left-hand triode of valve V8-7 is supplied with a short positive voltage pulse which causes the left-hand triode to conduct and the voltage on its plate to decrease. This voltage decrease is conducted through coupling capacitor C8-23 to the grid of the right-hand triode, which results in the plate current of this triode being decreased. This causes a decrease of the voltage drop across the valve common cathode resistor and, consequently, a decrease of the negative grid voltage on the valve left-hand triode in absolute magnitude.

.../ As a

As a result the plate current goes on to increase and the plate voltage on the left-hand triode decreases. Thus, an avalanche-like process of the circuit turnover develops ending in complete cut-off of the right-hand triode of the valve. The value of the plate current flowing through the left-hand triode after the turnover depends on the value of the voltage applied to the grid of this triode from potentiometer R8-27. This current is considerably smaller than that which has flown through the right-hand triode before the turnover, since the grid of the right-hand triode is connected to the positive voltage supply.

After the circuit has been turned over, capacitor C8-23 begins recharging comparatively slowly through a parallel combination of resistor R8-35 and resistance between the plate of the left-hand triode and earth and series-connected resistor R8-34. During the recharge the grid voltage of the right-hand triode gradually increases. The electron relay circuit remains in this new temporary steady state until this gradually increasing voltage reaches the value of the cut-off voltage.

At this moment the plate current appears in the right-hand triode due to which the total voltage drop across the common cathode resistor increases and, consequently, the grid voltage on the left-hand triode decreases. A decrease of the plate current of the left-hand triode brings about an increase of the voltage on its plate, which through coupling capacitor C8-23 is slowly passed to the grid of the right-hand triode and causes a further rise of its plate current.

Thus, start is given to a second avalanche-like process. As a result the circuit is returned to the initial position and remains in it until the next positive voltage pulse is applied to the grid of the left-hand triode.

If the grid of the valve left-hand triode is supplied with higher positive voltage (relative to earth) the plate current of the left-hand triode, when the circuit is turned over, will be greater. As a result

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.../the negative

the negative voltage drop on the plate of the left-hand triode and on the grid of the right-hand triode during the turnover of the circuit increases, and the cathode potential and the voltage level, at which the right-hand triode is cut off with the circuit turned over, increases (Fig.102, b). Thus, the time during which the right-hand triode is cut off increases and so does the duration of the voltage pulse produced by the electron relay.

The negative square pulses are applied from the plate of the left-hand triode of valve V8-7 to the grid of the left-hand triode of valve V8-14 of the strobe-pulse width electron relay through the differentiating circuit composed of capacitor C8-37 and resistor R8-67.

At the moment of the negative voltage drop the grid of the left-hand triode of valve V8-14 (6N8S) is fed with a short negative voltage pulse which does not affect the valve state. At the moment of the positive voltage drop across the input of the differentiating circuit, i.e. at the moment the delay pulse is no longer applied, the grid of the left-hand triode of valve V8-14 is supplied with a short positive voltage pulse which triggers the strobe-pulse width electron relay (Fig.103, a, b).

The circuit and the operating principle of the strobe-pulse width electron relay are the same as those of the delay electron relay. The strobe-pulse width electron relay differs from the latter by the circuit parameters. Besides, it has no pulse duration control. The width electron relay produces square strobe pulses of 9 microsec. duration (Fig.103, d).

The positive strobe pulses produced on the plate of the right-hand triode of valve V8-14 are applied through coupling capacitor C8-19 to the grid of the left-hand triode of valve V3-6 which functions as a cathode follower.

The cathode follower is used to cancel out the effect of the next selector valve V8-13 on the operation of the strobe-pulse width electron relay.

.../The trigger

The trigger pulse selector, employing valve V8-13 (6P9) is a final link of the trigger pulse forming circuit.

The control grid of this valve is supplied from the power pack with a negative voltage of about -5 V through resistor R8-61. But when the valve is operating the negative bias on its control grid is much greater in absolute value than 5 V. The positive voltage pulses are furnished from the trigger oscillator output, i.e. from the cathode of the right-hand triode of valve V8-6 to the control grid of the valve (V8-13) through coupling capacitor C8-35.

The time constant of the coupling circuit formed by capacitor C8-35 and resistor R8-61, equals 2200 microsec., i.e. very large as compared with the repetition rate of these pulses equal to 13.3 microsec. Due to the grid detection and large time constant of the discharge circuit of capacitor C8-35 (relative to the charge circuit) the automatic bias negative voltage is maintained on the control grid of the valve. At this voltage peaks of the grid voltage chart are slightly above the zero line (Fig.103, f). Thus, in time intervals between the voltage pulses of 75 Kc/s valve V8-13 is cut off on the control grid.

The screen grid of the valve is supplied from the power pack with a voltage of about -34 V through resistor R8-62 so that the valve proves to be cut off on the screen grid. The screen grid is supplied by the cathode follower with positive strobe pulses through coupling capacitor C8-36 (Fig.103, e) with a repetition frequency of 1.875 Kc/sec.

The valve (V8-13) is made conducting when the strobe pulse coincides with the peak of one of the voltage pulses of 75 Kc/s fed from the trigger pulse oscillator. With selected frequency relationship and the width of the strobe pulse (9 microsec.) smaller than the voltage cycle of the trigger pulse oscillator (13.3 microsec.) coincidence may take place only once every 40 voltage cycles of the trigger oscillator.

.../By regulating

By regulating the strobe pulse delay trigger pulses may be produced by the action of any of the first five voltage pulses of 75 Kc/s (B, C, D, E, F, in Fig.103, f) following the pulse that has caused triggering of the delay electron relay.

The delay is regulated by variable resistor R8-27, whose shaft is brought out to the front panel of the unit and is marked TRIGGER PULSE DELAY. This shaft is set in such a position at which the strobe pulse happens to be matched with the third voltage pulse of 75 Kc/s (pulse D in Fig.103, f). Thus, the trigger pulse generated by valve V8-13 is delayed for a period of 40 microsec. relative to the moment of triggering the gating and trigger pulse delay electron relay. Such delay of the trigger pulse is caused by the fact that the strobe delay circuit does not provide a delay that is less than 10 or 15 microsec. During triggering of valve V8-13 negative pulse is produced on its plate (Fig.103, g).

From the plate of valve V8-13 the trigger pulses are furnished through coupling capacitor C8-34 to the primary winding of step-down pulse transformer Tr8-3. This transformer is required for matching the output resistance of the selector stage with the low input resistance of the cable through which the trigger pulse voltage is conducted to trigger the transmitter and the plan-position indicator system.

Coarse-Range Tube Gating

The circuit forming the coarse range tube gating consists of a gating delay electron relay (V8-7) which is simultaneously used for the trigger pulse delay. The operation of this relay is detailed above. The gating and trigger pulse delay is simultaneously regulated by potentiometer R8-27 whose shaft is brought out to the front panel of the unit and marked TRIGGER PULSE DELAY.

The positive pulses of the square-wave voltage taken from the plate of the right-hand triode of valve V8-7 with the wide gating switch in

.../position 0

position 0 - 40 km., are furnished through the differentiating circuit to the gating width electron relay (V8-15, valve of the 6N8S type), whose simplified diagram is presented in Fig.104.

This circuit is similar to that of the frequency division multivibrator considered above, and differs from it in the arrangement of the grids of both triodes of the valve which are connected through resistors not to the cathodes but to the D.C. voltage supplies.

The grid of the left-hand triode of valve V8-15 is supplied with a positive voltage of about +4 V from the divider formed by resistors R8-70 and R8-78, while the grid of the right-hand one with a negative voltage of -34 V from the power pack. As a result the circuit cannot operate as an autodyne and in the absence of trigger pulses the left-hand triode of the valve is always conducting, whereas the right-hand one is cut off.

Positive voltage pulses from the gating delay electron relay and the trigger pulse, are applied to the grid of the left-hand triode V8-15 through the differentiating circuit composed of the capacitor C8-39 and the equivalent A.C. resistance between the grid of the left-hand triode and earth.

The time constant of the coupling circuit is found to be very small as compared with the delay pulse duration. Therefore, the grid of the left-hand triode at the beginning of the delay pulse is supplied with a short positive pulse, while at the end of the delay pulse, with a negative voltage pulse.

The positive voltage pulse, coming to the grid of the conducting triode, cannot change the circuit state, while the negative pulse gives start to an avalanche-like process of cutting off the left-hand triode and triggering the right-hand one, i.e. triggers the electron relay.

The duration of the circuit turnover is determined by the rate of discharge of capacitor C8-41, during which the grid voltage of the left-hand triode rises steadily. At the moment it reaches the cut-off level a

second avalanche-like process occurs which causes the circuit to return to the initial position.

Generated on the plate of the left-hand triode are positive pulses of the square-wave voltage with an amplitude of about 100 V which are used for gating the sweep on the coarse range indicator.

The duration of these pulses is regulated by variable resistor R8-77 whose shaft is brought out to the front panel of the unit and is marked GATING WIDTH.

Despite the fact that the gating and trigger pulse are delayed and regulated by the same electron relay, the beginning of the coarse range indicator sweep gating somewhat precedes the end of the transmitter pulse.

When regulating the pulse duration, shaft GATING WIDTH is set so that almost the complete circle of the coarse range sweep (about 39 km. on the range scale) will be gated.

Strobe Pulse Formation

The strobe pulses serve to form the very narrow gate, to gate part of the fine range indicator sweep and a small part of the sweep on the coarse range indicator and the indicator of the plan-position indicator.

The strobe pulse forming channel is composed of a delay circuit (Fig.106), consisting of trigger valve V8-9 (6Z4), control valve V8-10 (6Z4), limiter V8-11 (6H6S) and quenching valve V8-17 (6P9) and gating width electron relay, employing valve V8-16 (6N8S).

The voltage from the multivibrator 1.875 Kc/s is applied to the suppressor grid of the strobe delay circuit triggering valve through the differentiating circuit formed by capacitor C8-29 and resistor R8-6.

In the absence of the voltage pulses supplied by the multivibrator 1.875 Kc/s, the triggering valve is conducting as its control grid is connected through resistor R8-55A to the plate voltage supply of +270 V. The valve circuit conducts the plate current which sets up a voltage drop

of about 220 V across resistors R8-69 and R8-93, which results in the voltage on the valve plate relative to earth being equal to about 50 V.

The suppressor grid of control valve V8-10 is connected to the mid-point of the divider, composed of resistors R8-10 and R8-14, which is connected between the plate of the triggering valve and the point under 210 V supplied from the automatic range finder power pack, therefore, the voltage on the suppressor grid is found to be equal to approximately - 80 V. With such a voltage on the suppressor grid the control valve is cut off on the plate circuit. The plate of the control valve is connected to that of triode V8-11A whose cathode is supplied with a positive voltage of +215 V from the divider, formed by resistors R8-33 and R8-45 AB, and through resistor R8-59 to the plate voltage supply of +270 V.

Provided the voltage on the diode cathode is less than that of the plate supply, the current will flow through resistor R8-59 and diode V8-11A. The differential resistance of the conducting diode is negligible and, therefore, the voltage on its plate and, consequently, on the plate of the control valve is set equal to +215 V.

When the trigger valve is acted on by the negative pulse produced as a result of differentiation of voltage pulses supplied by the multivibrator 1.875 Kc/s, the plate current of the trigger valve sharply decreases while the plate voltage sharply increases.

The positive voltage drop is applied through coupling capacitor C8-67 to the suppressor grid of the control valve removing the cut-off bias on suppressor grid and the plate current appears in the plate circuit of this valve. The current decreases the plate potential of the control valve. The voltage decrease is conducted through coupling capacitor C8-30 to the control grid of the trigger valve, thereby adding to its cut-off. This in turn increases the plate voltage of the trigger valve and the voltage on the pentode grid of the control valve. The process resulting in cutting off the trigger valve and triggering the control valve goes on in an avalanche-like manner.

Simultaneously the negative voltage drop on the plate of the control valve is conducted through coupling capacitors C8-76 and C8-77 (Fig.92, see Album) to its control grid, thus opposing the plate current rise. At the end of the avalanche-like process the voltage on the control grid is found to be approximately equal to the cut-off voltage. At the moment the voltage drops on the plate of the control valve diode V8-11A is cut off.

After the avalanche-like process is over coupling capacitors C8-76 and C8-77 begin discharging through an equivalent resistance composed of parallel connected resistors R8-59 and D.C. resistance of valve V8-10 as well as resistor R8-55B connected in series with them. As coupling capacitors C8-76, C8-77 discharge, the control grid voltage of valve V8-10 gradually rises. This rise involves an increase of the plate current of control valve V8-10 and, consequently, a decrease of the voltage on its plate, which in turn is conducted through coupling capacitors C8-77, C8-76 to the control grid of valve V8-10, thus preventing a voltage rise on it. As a result, the plate voltage drops at a constant rate, i.e. linearly.

The voltage drop on the plate of valve V8-10 is applied through coupling capacitor C8-30 to the control grid of the trigger valve thereby keeping it cut off.

The linear voltage drop on the control valve plate stops at the moment it becomes equal to the plate voltage of diode V8-11B.

Diode V8-11B is connected into the positive feedback circuit of the quenching valve V8-17. In this case the quenching valve (V8-17) is conducting since its control grid due to connection of leak resistance R8-96 to the positive voltage supply, is under a low positive voltage (fractions of a volt) and a heavy cathode current of valve V8-17 flows through the secondary winding of feedback transformer Tr8-4.

When the plate voltage of the control valve becomes equal to the plate voltage of diode V8-11B, the diode begins to conduct closing the positive

/feedback circuit

feedback circuit of the quenching valve. The diode current sets up a voltage drop across resistor R8-49, due to which the plate potential of diode V8-11B decreases and the negative voltage drop on the diode plate is applied through coupling capacitor C8-51 to the control grid of the quenching valve, thus decreasing its cathode current. The negative pulse produced on the quenching valve cathode further reduces the cathode potential of diode V8-11B, thereby decreasing the quenching valve current.

Thus, due to the positive feedback through transformer Tr8-4 the quenching valve is quickly cut off and the negative voltage pulse which appears in its cathode circuit passes via coupling capacitor C8-74 to the control grid of the control valve, thus cutting it off. This leads to an increase of the voltage on the control valve plate and, consequently, to an increase of the potential on the control grid of the trigger valve.

The trigger valve is made conducting, the voltage on its grid drops and so does the voltage on the suppressor grid of the control valve. The described process goes on in an avalanche-like manner. After the plate voltage of the control valve has dropped linearly, the pulse trailing edge is formed on the plate of the trigger valve. The trailing edge is the steepest section as the voltage drop on its plate is limited only by spurious capacitances, while the voltage rise on the control grid plate goes on with the time constant determined by capacitors C8-30, C8-76, C8-77 and resistor R8-59.

An increase of the control valve plate voltage causes an increase of the cathode voltage of diode V8-11B, the diode stops conducting and the quenching valve is triggered.

The voltage rise on the plate of the control valve lasts until it reaches the cathode voltage of diode V8-11A, i.e. +215 V. From this moment the diode is conducting and further voltage rise on the control valve plate ceases.

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.../The trailing

The trailing edge of the voltage pulse produced on the trigger valve plate is used for triggering the strobe-pulse width electron relay. The moment the pulse trailing edge appears on the plate of the trigger valve is determined by the duration of the linear voltage drop on the plate of the control valve. The duration of the linear drop is in turn regulated by the voltage change on the plate of diode V8-11B. Voltage to the diode plate is applied from the mid-point of strobe delay potentiometer R4-21 placed in the range mechanism unit and kinematically coupled to the range handwheel.

Rotating the range handwheel clockwise decreases the plate voltage of diode V8-11B (voltage taken off the potentiometer mid-point) and therefore, increases the duration of the linear voltage drop on the control valve plate. In this case the trailing edge of the voltage pulse on the plate of valve V8-9 is shifted in time while triggering the strobe width electron relay.

The circuit parameters are selected so that the duration of the linear voltage drop on the plate of the control valve and, consequently, the appearance of the pulse trailing edge on the trigger valve plate can be regulated by changing the voltage on the plate of diode V8-11B, taken off the mid-point of the strobe delay potentiometer, within the range of 15 to 320 microsec., which covers the required range band of 40 km.

It is necessary that the strobe pulses should be produced simultaneously with the transmitter pulses with the strobe delay potentiometer slider in one extreme position corresponding to zero position of the range mechanism scales and with the other extreme position corresponding to 40 km. distance.

Voltage to the strobe delay potentiometer (R4-21) is fed from the divider composed of resistors R4-22, R4-27, R4-23, R4-24AB, R4-25 and R4-26 located in the range mechanism unit. The strobe initial position corresponding to zero range is regulated by variable resistor R4-23, whereas the strobe position corresponding to 40 km. range, by variable

.../resistor R4-25.

resistor R4-25. The slotted shaft of both resistors are brought out to the front panel of the range mechanism unit and are marked STROBE CONTROL, BEGINNING - END.

Fig.106 shows the location of strobe pulses in time at two extreme positions of the slider of strobe delay potentiometer R4-21.

The voltage pulse trailing edge on the trigger valve plate is used to trigger the strobe pulse width electron relay employing valve V8-16 of the 6N8S type (Fig.92). The electron relay is similar in design and operating principle to the gating width electron relay and differs from it by the circuit parameters. The duration of the strobe pulses produced by the strobe-pulse width electron relay is regulated by variable resistor R8-88 whose shaft is brought out to the front panel of the unit and is marked STROBE WIDTH.

The strobe-width electron relay produces the following two pulses:

1. The negative strobe pulse of 15 - 20-volt amplitude taken from resistor R8-51. The pulse is furnished to the cathode of the coarse range indicator and is used as an electronic marker. When rotating the range handwheel, the electronic marker moves along the sweep trace brightening separate sections of the coarse range indicator sweep. When setting the electronic marker to the target echo, an approximate target range (within 1 km.) corresponding to this setting can be read on the coarse range indicator scale.

2. The positive strobe pulse of 110 - 120-volt amplitude taken from the right-hand plate of triode V8-16. The pulse is used for gating the sweep of the fine range indicator and triggering the selector valve of the very narrow gate circuit. Besides, the pulse is applied to the plan-position indicator unit to brighten a sweep section corresponding to the set range on the range indicators. Strobe pulses are furnished to the very narrow gate and range indicator and the plan-position indicator

.../through long

through long shielded cables. Therefore, in order to keep as steep as possible the slope of the strobe pulse edges, which may be made less steep by large capacitance of the cables, the strobe pulse voltage is fed to these units through a cathode follower utilizing valve V8-8B (6N8S).

Cathode Follower 15 Kc/s

The cathode follower 15 Kc/s (Fig.107) employing valve V8-8A (the left half of valve V8-8) serves to produce negative voltage pulses supplied to the plan-position indicator system for controlling the range marker forming circuit.

The multivibrator (15 Kc/s) voltage is applied to the grid of the cathode follower through a differentiating circuit formed by coupling capacitor C8-25 and resistors R8-39 and R8-40. Thus obtained on the grid are positive and negative pulses of 15 Kc/s frequency.

The amplitude of the positive voltage pulses, obtained as the result of differentiation of flat and small positive voltage drops of the multivibrator 15 Kc/s is appreciably lower than that of the negative pulses, because in addition during their formation resistors R8-39 and R8-40 are found to be shunted by grid - cathode conducting section of valve V8-8A.

The negative voltage pulses on the cathode follower grid corresponding to synchronized fronts of the multivibrator voltage 15 Kc/s have an amplitude of about 100 V.

The operation of the negative voltage pulses which trigger the range marker forming circuit should not be confined to the valve cutting off, because of this the control grid of the cathode follower is supplied with positive voltage taken from divider R8-39, R8-40. As a result the bias voltage on the grid (relative to the cathode) equals zero. With such bias on the grid the negative voltage pulses obtained due to differentiation of voltage pulses of the multivibrator 15 Kc/s pass easily through the cathode follower without cutting it off.

.../The wave-forms

The wave-forms of voltages acting in the cathode follower circuit are presented in Fig.107.

The negative voltage pulses of 15 Kc/s are taken off cathode load R8-41 and are furnished to the plan-position indicator unit to trigger the range marker forming circuit.

4. RANGE AND VERY NARROW GATE INDICATOR UNIT

The range and very narrow gate indicator unit is designed to observe the signals reflected from the target visually and to select the tracked target by matching the electronic marker with the target echo.

Formed in the unit are very narrow gate pulses of 0.3 microsec. duration which control the automatic tracking channel of the receiving system.

The front and the top view of the unit is presented in Figs 108 and 109, whereas the key diagram in Fig.110 (See Album). The range and very narrow gate indicator unit is comprised of the indicator part and final stages of the very narrow gate and the fine range indicator electronic marker forming circuit. Used as indicators in the unit are two cathode-ray tubes, type 8L030 : a coarse range indicator (V3-7) and a fine range indicator (V3-6). Location of the echo signal on the sweep circular traces of the range indicators determines the target slant range (Fig.245). For this purpose the operator rotates the handwheel to match the electronic markers of the fine and coarse range indicators with the target echo signal and reads the range off the range mechanism scales.

The circuit indicator part is composed of two cathode-ray tubes, four resonant transformers and a voltage divider.

The cathode-ray tubes are provided with two pairs of deflecting plates at right angles to each other and an additional deflecting electrode sealed in the screen centre (the central electrode).

.../The deflecting

The deflecting plates of the fine range indicator (V3-6) are fed with sine-wave voltages of 75 Kc/s from the secondary windings of resonant transformers Tr3-2 and Tr3-3 (Fig.110). The primary windings of these transformers are supplied with voltage from the range unit phase shifting transformer Tr8-1 through contacts 7 and 3 of connector Zw3-2.

To match the sweep centre with the centre of the fine range indicator screen one deflecting plate of each pair is connected through leak resistances (R3-6, R3-9) to earth, and the other two plates to the sliders of potentiometers R3-27, R3-26 through resistors R3-7, R3-8. The potentiometers are fed with a voltage of -100 V from resistor R3-22 of the -1.700-volt divider and +100 V from resistor R3-28 of the +490-volt divider. The potentiometer sliders are set so that the centre of the sweep coincides with that of the indicator. The slotted shafts of both potentiometers are brought out to the front panel of the unit and are marked CENTRING.

The sweep voltage is applied to the coarse range indicator (V3-7) from step-up resonant transformers Tr3-4, Tr3-5, tuned to a frequency of 3.75 Kc/s.

The step-up resonant transformers are tuned in resonance with the applied voltages by means of alsifer cores. The resonance tuning permits an additional filtration of output voltages from harmonics inherent to the voltages produced by the phase shifting transformers of the range unit.

Voltage is applied to the primary windings of these transformers from the range unit through contacts 8 and 10 of blade connector Zw3-2.

The centre of sweep 40 km. is set with the help of two potentiometers R3-31, R3-32, which are connected in parallel to potentiometers R3-26, R3-27. Voltage from the potentiometers is fed to the horizontal and vertical deflecting plates through resistors R3-36 and R3-34. The other two plates are earthed through resistors R3-35 and R3-33.

The shafts of potentiometers R3-31 and R3-32 are brought out to the front panel of the unit and are marked CENTRING.

Voltages to the electrodes of the fine and coarse range indicators are taken out from a divider formed by resistors R3-13 - R3-22. The divider is fed through high-voltage connector Zw3-3 with a voltage of -1700 V from the rectifier of the power pack of the range measuring and plan-position indicator systems.

Voltages to the cathode-ray tube electrodes are taken out from potentiometers R3-13, R3-14, provided in the voltage divider. Turning the potentiometer knobs changes the sweep brightness. The knobbed shafts of potentiometers R3-13, R3-14 are brought out to the front panel of the unit and marked BRIGHTNESS.

Voltages to the first anodes of the cathode-ray tubes are applied from potentiometers R3-16, R3-17, whose knobbed shafts are brought out to the front panel of the unit and marked FOCUS. By operating these knobs the beam is focused.

The second anodes of the fine and coarse range indicators are earthed, while the cathodes are connected to one of the divider points under a negative voltage of somewhat lower than -1700 V.

Voltage to heat the cathode-ray tubes is applied from special transformer Tr3-1, whose secondary winding is provided with high-voltage insulation because it is under -1700 volts relative to earth. To brighten the sweep of the coarse range indicator, strobe pulses of positive polarity are furnished to the control electrode of the indicator from the range unit through capacitor C3-8. Fed to the cathode-ray tube cathode through capacitor C3-13 are positive pulses of the electronic marker which create two gaps on the sweep of the fine range indicator.

To brighten one revolution of the sweep the control electrode of the coarse range indicator is supplied with positive strobe pulses through capacitor C3-12. The cathode of the coarse range tube is fed through capacitor C3-7 with negative strobe pulses which create an electronic

marker on the coarse range indicator. The voltage pulses of the target echo signals are applied from the range channel amplifier output to the central deflecting electrodes of the cathode-ray tubes through connector Zw3-4.

The circuit supplying voltage to the central electrodes of tubes connected to each other is provided with selector switch W3-1 located on the front panel of the unit and marked OPERATION - CHECK.

When setting selector switch W3-1 in position OPERATION the voltage pulses of the target echo signals are fed to the central electrodes of the cathode-ray tubes.

With selector switch W3-1 in position CHECK the fine and coarse range indicators are used for checking voltages applied to the central electrode when testing units through connector Zw3-7. Connector Zw3-7 is located on the front panel of the unit and is marked CENTRAL ELECTRODE.

The range and very narrow gate indicator unit accommodates the final stages of the circuit forming the very narrow gate and electronic marker of the fine range indicator.

The wave-forms of the voltage acting in the very narrow gate and electronic marker circuit and their time relationships are shown in Fig.112.

The initial voltage to form the very narrow gate and electronic marker is a voltage of 75 Kc/s whose phase changes in proportion to the amount the range handwheel is turned. This voltage is applied to connector Zw3-6 (Fig.110) of the range and very narrow gate indicator unit from the range mechanism unit. From connector Zw3-6 the sine-wave voltage of 75 Kc/s is impressed through an adapter on the control grid of the first clipper amplifier (V3-1).

Clipper Amplifier

The first clipper amplifier employs the left half of double triode 6N8S (V3-1A).

SECRET

.../The triode

The triode grid is fed with a voltage of 75 Kc/s having an amplitude of about 5 - 6 V, while an A.C. voltage of 60 V is taken out from its plate (Fig.112, a).

The wave-form of this voltage slightly differs from the sine-wave form as a result of clipping on account of the lower bend of the valve grid characteristic curve. Voltage from the amplifier plate is applied through coupling capacitor C3-22 (Fig.111) to choke L3-1, which through resistor R3-44 is connected to the grid of the second clipper amplifier, i.e. the right-hand triode of valve V3-1B.

During positive half-cycles right-hand triode V3-1 conducts the grid current which develops a voltage drop across resistor R3-44, therefore the voltage between the grid and the cathode during these half-cycles is maintained approximately at zero level. Thus, grid current causes clipping of positive half-cycles of the sine-wave voltage (Fig.112, b).

This voltage is additionally clipped in the valve on account of the lower bend of the valve grid characteristic curve. Therefore, the valve plate current is nearly square.

If the grid circuit of clipper amplifier V3-1A (Fig.110) had been provided with resistor instead of choke L3-1, then due to the grid current flow through the resistor a voltage drop would have been developed whose value depends upon the average value of the valve grid current. Therefore from the unearthed end of this resistor voltage would be applied to the valve grid through resistor R3-44, the voltage consisting of the A.C. component supplied from the plate of the left-hand triode and the negative D.C. component depending in value upon the amplitude of the A.C. component. In this case the right-hand triode would be triggered and cut off slower. Therefore, the current wave-form in its plate circuit would be less close to the square wave-form. In this case the steepness of the current drops as well as the phase (relative to the output voltage of the phase shifter)

.../would be

would be in greater degree dependent upon the amplitude of the A.C. voltage coming from the plate of the left-hand triode.

When using a choke possessing a very low resistance the voltage D.C. component at its unearthed end is practically equal to zero, due to which the right-hand triode is triggered or cut off by the action of the most steep sections of the A.C. voltage taken off the plate of the left-hand triode. Thus in this case maximum steepness of the clipper amplifier plate current drops is obtained and dependence of the phase of these drops (relative to the output voltage of the phase shifter) upon the amplitude of the A.C. voltage on the plate of the left-hand triode is eliminated considerably.

During the action of positive half-cycles of the voltage, the clipper amplifier conducts a grid current which develops a voltage drop across resistor R3-44 proportional to the input voltage of negative polarity. As a result the clipper amplifier control grid is supplied only with negative half-cycles of the sine-wave voltage. In the valve this voltage is amplified and clipped additionally on account of the lower bend of the valve characteristic curve.

Thus, a voltage of approximately a square wave-form is obtained in the plate circuit of the clipper amplifier.

From the clipper amplifier plate the voltage is fed to the grid of selector V3-2 employing valve 6Z4.

Selector

The circuit of the selector control grid is provided with choke L3-2 whose inductance and inter-turn capacitance constitute an oscillatory circuit. The oscillation period of the circuit is about 1 microsec. At the moment the voltage drops on the plate of the clipper amplifier oscillations are excited in the circuit.

.../To increase

To increase damping the circuit is shunted by resistor R3-45. As a result each time the circuit is shocked into excitation the first half period of oscillations exceeds the succeeding ones in its amplitude. Thus, it may be considered that for one voltage cycle of 75 Kc/s one positive and one negative voltage pulse of about 1 microsec. duration are produced on choke L3-2 (Fig.112, c).

The beginning of these pulses is always coincident with the moment the clipping triode is triggered or cut off. Therefore, when the phase shifter rotor is turned through any angle the phase of voltage pulses on choke L3-2 (relative to the voltage applied to the input of the phase shifter) changes by the same angle.

The voltage pulses are directly applied from choke L3-2 (Fig.110) to the control grid of the selector, i.e. valve V3-2 (6Z4). Due to a large value of the selector cathode load R3-46 the voltage on the selector cathode has a value approximating the cut-off voltage of the valve. Simultaneously the selector valve is cut off on the suppressor grid by a negative voltage of -90 V supplied from the power pack of the range and plan-position indicator systems through contact 3 of blade connector Zw3-1.

During every cycle of 75 Kc/s voltage one positive and one negative pulse are produced on the control grid of the selector. The suppressor grid of the selector is supplied with positive strobe pulses triggering the valve (Fig.112, d) through capacitor C3-27.

Only one positive pulse coinciding with the strobe pulse is amplified on the selector control grid during every cycle of 1.875 Kc/s voltage. Negative pulses of 1.875 Kc/s (Fig.112, e) are produced on the selector plate load R3-47 (Fig.110).

These pulses trigger a blocking oscillator, employing valve V3-3 of the 6N8S type (Fig.110), which forms very narrow gate pulses.

Very Narrow Gate Blocking Oscillator

Fig.113 is a representation of the blocking oscillator circuit.

In the absence of pulses from the selector plate valve V3-3 of the blocking oscillator is cut off by a negative voltage of -28 V applied through resistor R3-50 from the power pack of the range and plan-position indicator systems. This voltage (-28 V) is regulated by potentiometer R5-18, whose shaft is brought out to the front panel of the power pack and is marked BIAS.

Placed into the plate circuit of the blocking oscillator is the primary winding of transformer Tr3-8. The secondary winding of the transformer is connected to the control grid. When the negative pulse from the selector plate is applied through capacitor C3-26 to the plate of the blocking oscillator a current directed from the power pack to capacitor C3-26 begins flowing through the plate winding of pulse transformer Tr3-8. A magnetic flux set up the transformer core crosses the turns of its windings and as a result a certain voltage is obtained across the terminals of the secondary grid winding. The leads of the secondary winding are connected so that the plus of this voltage during an increase of the magnetic flux is found to be applied to the valve grid. The valve is made conducting, its plate current flowing through the transformer primary winding causes an increase in the magnectic flux which brings about further increase of the voltage on the grid. Thus, the plate current and grid voltage rise in an avalanche-like manner.

The voltage across the plate and grid windings of transformer Tr3-3 is proportional to the rate of increase of the valve plate and grid currents, both currents acting in opposite directions. While the rate of the plate current rise exceeds that of the grid current rise, the plate voltage of the valve continues to fall rapidly, whereas the grid voltage to rise rapidly. However, an appreciable decrease of the plate voltage due to

.../the valve

the valve plate reaction, retards the plate current rise and accelerates the grid current rise. The avalanche-like process is retarded and then stopped (when voltage drops across the windings caused by both currents are compensated).

A small voltage drop on the control grid due to the charge current of capacitor C3-30 (through grid- cathode section) gives start to a second avalanche-like process, but this time in opposite direction. The plate voltage begins to rapidly rise, whereas the grid voltage to fall. This results in an increase of the rate of the plate current drop and in a decrease of the rate of the grid current drop, which maintains the avalanche-like process. The second avalanche-like process brings about a sharp drop of the plate current. This drop determines the trailing (negative) edge of the blocking oscillator pulse. Thus the blocking oscillator produces back-to-back saw-tooth pulses of small duration depending upon design data of transformer Tr3-8. The given circuit employs a transformer making it possible to obtain a pulse of 0.3 microsec. duration.

The second cycle of the avalanche-like process lasts until the valve is cut off again. During the positive voltage peak on the control grid heavy grid currents charging capacitor C3-30 flow through the blocking oscillator valve. As a result the potential of point A is considerably reduced.

When the valve is cut off capacitor C3-30 begins discharging through resistor R3-50 and the potential of point A rises, but this potential reaches only -28 V and therefore it cannot make the valve conducting.

The valve remains in this state until the next pulse arrives from the selector plate.

Placed in the blocking oscillator circuit is a decoupling circuit formed by resistor R3-52 and capacitor C3-28, which stores high power required during the generation of the pulse by the blocking oscillator.

.../The presence

The presence of such a circuit increases the operation stability of the remaining stages fed from the source of stabilized voltage of 270 V since, despite a heavy current flowing through valve V3-3, the current consumed from the source is practically the same.

The valve plate current flowing in the interval between the beginning of the first and the end of the second avalanche-like process creates the very narrow gate pulse of 0.3 microsec. duration (Fig.112, f) across cathode load R3-51 and R3-54. The pulse is furnished through capacitor C3-29 (Fig.113) to the target simulator and the band-elimination filter composed of series and parallel circuits tuned to the receiver intermediate frequency. This filter serves to suppress in the very narrow gate pulse spectrum those harmonic components of oscillations which approximate the receiver intermediate frequency.

From the filter the very narrow gate pulse is passed to the automatic tracking channel of the receiving system.

The positive pulse from the cathode load R3-54 is furnished to the automatic range finder unit through delay line 0.17 microsec.

First and Second Electronic Marker
Blocking Oscillators

The first and second electronic marker blocking oscillators employ valves V3-4 and V3-5 of the 6N8S type (Fig.110). The first blocking oscillator is triggered by the negative pulse, taken from the plate load of the very narrow gate blocking oscillator (V3-3).

The cathode circuit of the first electronic marker blocking oscillator is provided with a delay line for 0.4 microsec. opened at the end. The pulse formed on cathode load R3-53 is conducted to the delay line and is reflected from its end to cathode resistor R3-53 in 0.8 microsec. These two pulses are furnished from the cathode load of the first blocking oscillator to the second one and trigger the latter. Two positive pulses of the electronic marker separated by a 0.8 microsec. interval are produced in the cathode circuit of the second blocking oscillator.

Transformers Tr3-6, Tr3-7 of the electronic marker blocking oscillators have the same characteristics as transformer Tr3-8.

The decoupling circuit of the first and second blocking oscillators is comprised of resistor R3-57 and capacitor C3-43. This circuit is designed to serve the same purpose as circuit R3-52, C3-28 of the very narrow gate blocking oscillator. The operation of both blocking oscillators is similar to that of the very narrow gate blocking oscillator.

The electronic marker pulses are applied from cathode load R3-3 (Fig.112, h) to the cathode of the fine range indicator.

Rotation of the range handwheel changes the phase of the sine-wave voltage, 75 Kc/s, at the output of the phase shifter, the very narrow gate pulses and electronic marker being shifted in time relative to the beginning of the sweep.

The range handwheel is set so as to ensure symmetrical location of electronic markers relative to the target echo.

5. RANGE MECHANISM UNIT

The front panel of the range mechanism unit is shown in Figs 114 and 115, while the key diagram of the unit in Fig.116 (See Album).

The range mechanism unit consists of a phase shifting network, a distribution mechanism and a scale mechanism.

Phase Shifting Network

The phase shifting network is composed of a single-stage input amplifier, a phase splitting bridge, a capacitive phase shifter and a final amplifier. The network is intended for shifting the range indicator and very narrow gate electronic marker relative to the range reading zero.

The input amplifier employs the left-hand triode of valve V4-1 (6N8S) and is designed to amplify the input voltage coming from the range unit.

The voltage of 75 kilocycle frequency coming from the range unit is applied to the control grid of the left-hand triode of valve V4-1 through

connector Zw4-1 and potentiometer R4-20. The potentiometer serves to set the amplitude of the input voltage to 0.85 ± 0.5 V. Its slotted shaft is brought out to the chassis of the unit.

The amplified voltage 75 Kc/s from the plate of the left-hand triode is impressed on the grid of the cathode follower which utilizes the right-hand triode of the same valve V4-1.

The amplitude of the sine-wave voltage on the cathode of the right-hand triode is approximately equal to 20 V. The cathode follower load is step-down transformer Tr4-1 with a ratio of 3:1 between the primary and secondary winding turns. The cathode follower with step-down transformer serves to match low-resistance input of the phase shifter bridge with the high-resistance output of the amplifier. The voltage from the transformer secondary winding is fed to the bridge circuit of the phase shifter (Fig.117, a, b).

The phase shifter bridge circuit is composed of a voltage divider employing resistors R4-6, R4-7, R4-8 and two parallel branches C4-6, R4-9, R4-10 and R4-11, R4-12, C4-8. The mid-point of the divider (the slider of potentiometer R4-7) is earthed. As a result A.C. sine-wave voltages equal in amplitude, but shifted in phase by 180° act between points A and B of the circuit and earth (point O).

The amplitude of these two voltages is accurately balanced by moving the ground slider of potentiometer R4-7 whose shaft is brought out to the front panel of the unit and is marked BALANCE-1.

To ensure precise phase opposition of these voltages it is necessary that not only pure resistances between point A and earth and between point B and earth, but A.C. reactance 75 Kc/s, should be equal in magnitude. It should be borne in mind that susceptances which are hardly calculated beforehand, are provided in sections AO and BO of the circuit due to distributed capacitances of the transformer secondary winding designated

.../in Fig.117,

in Fig.117, a, as capacitors C_A and C_B. Therefore, to balance susceptances of sections AO and BO accurately the circuit is provided with fixed capacitor C4-5, trimming capacitor C4-7 by means of which an accurate phase opposition of the voltage in points A and B (relative to earth) is obtained. The shaft of the capacitor C4-7 vane is brought out to the front panel and is marked PHASE.

Let us consider the bridge vector diagram (Fig.117, b) and development of voltage in point B - vector U_{CO} (left branch of the bridge). Vector U_{AB} indicates the voltage of the secondary winding of transformer Tr4-1 acting between points A and B of the bridge. Vectors U_{AO} and U_{BO} indicate voltages acting in points A and B relative to earth. Voltage across capacitor C4-6 (vector U_{AB}) is always shifted by 90^o relative to voltage drops across resistors R4-9, R4-10 (vector U_{CB}) and vector sum of voltages U_{AC} and U_{CB} always equals voltage U_{AB} applied to the branch. Branch R4-9, R4-10 conducts current I (Fig.117, b) and in case of equality of pure resistance and capacity reactance in absolute value, equality of amplitudes of voltages U_{AC} and U_{CB} will be obtained in the branch. In this case voltage U_{CO} in point C relative to earth and equal to the vector sum of voltages U_{BO} and U_{CB} leads voltage U_{AB} applied to the branch in phase precisely by 90^o.

When pure resistance and capacity reactance are equal in the right-hand branch, voltage U_{DO} in point D relative to earth lags in phase precisely by 90^o from voltage U_{AB} applied to the branch and is opposite in phase to voltage U_{CO}.

Pure resistance and capacity reactance in each branch of the bridge are balanced precisely by means of variable resistors R4-10 and R4-11 whose slotted shafts are brought out to the front panel of the unit and are marked BALANCE-2 and BALANCE-3.

Voltages from four bridge points (U_{AO}, U_{BO}, U_{CO} and U_{DO}) are applied to the capacitive phase shifter (Fig.118) composed of two stator discs

and a rotor. The first stator disc consists of four sectors insulated from each other; the second disc is solid. Sectors 1, 2, 3, 4 are fed with voltages from points C, B, D and A of the bridge. Sectors 1, 2, 3, 4 and disc 5 constitute four capacitors (Fig.118, b). The output voltage of the phase shifter is taken off between disc 5 and earth.

If all four capacitors (C_1, C_2, C_3, C_4) had the same value, the current in the phase shifter load and voltage V_{output} across it would amount to zero, since four voltages U_{AO}, U_{DO}, U_{BO}, and U_{CO} acting in the circuit are equal in value and shifted in phase by 90° with respect to each other. But due to presence of the phase shifter rotor these four capacitances will never be equal to each other.

The rotor comprises an insulation disc having specific inductive capacitance of about 6. The disc is set on the rotation shaft eccentrically.

If, for instance, the disc stands against sector 1, the capacitance C_1 exceeds any of the three capacitors and an A.C. current caused by voltage U_{CO} appears in the load. In this case the current circuit has minimum capacitive reactance.

If the phase shifter rotor is then turned through 90° the insulation disc will stand against sector 2 and the capacitance C_2 will be maximum and current caused by voltage U_{BO} will flow through the load. Thus, the current in the load and voltage U_{output} in the second case will be 90° out of phase as compared with those in the first case.

Displacement of the insulation disc centre off the rotor shaft should be selected so that during the rotor rotation the phase of the output voltage changes linearly depending upon the angle of turning. The shaft of the phase shifter rotor is mechanically coupled to the main shaft of the range mechanism with gear ratio 1:1. The output voltage of the phase shifter is used to produce very narrow gate pulses and the electronic marker of the fine range indicator. Therefore, the change of this voltage

phase by any angle causes the electronic marker on the fine range indicator to move through the same angle.

One complete revolution of the fine range tube electronic marker corresponds to a complete revolution of the phase shifter rotor. In this case the phase of the voltage taken from the phase shifter changes by 360° and location of the very narrow gate pulse and pulses of the fine range indicator electronic marker changes by 2000 m. on the scale.

The voltage shifted in phase is applied from the phase shifter output to the grid of amplifier valve V4-2, type 6Z4 (Fig.116). Voltage from the amplifier plate is fed to the range and very narrow gate indicator unit through connector Zw4-2.

To check the output voltage taken off the plate of amplifier V4-2 (6Z4) use is made of jack G4-6 (OUTPUT VOLTAGE) coupled to connector Zw4-2.

Distribution Mechanism

The construction of the range mechanism unit makes possible manual and automatic target tracking in range. In this case the slant range data are transmitted to the anti-aircraft director by two transmitting selsyns of the DI-511 type.

The kinematic diagram of the distribution mechanism is presented in Fig.119 (See Album).

The target is tracked manually by rotating the manual tracking handwheel, and automatically, by automatic tracking motor M4-2, type ASM-200.

The manual tracking handwheel is coupled with the main shaft not rigidly, but through a spring friction clutch which makes it possible to transmit from the handwheel to the main shaft only a limited torque not exceeding the friction torque in the friction clutch. As a result, when the main shaft is stopped by the mechanical limiter in either extreme position (beyond the operating range band of 0 - 40 km.) further rotation of the handwheel is not accompanied by transmission of excessive torques

to the main shaft. This precludes the possibility of breakage of separate system elements.

During automatic tracking rotation should not be imparted to the handwheel. For this purpose a differential friction brake is mounted on the shaft of bevel gear Z - 34. The pin of the brake adjusting screw is placed under the plug (under the cup head screw) on the cover of the distribution mechanism (Fig.120).

Automatic tracking motor M4-2 (Fig.116) is provided with a control and a supply winding. Voltage to the motor control winding is applied through contacts 2 and 4, contact 4 being earthed. Contacts 1 and 3 of the motor are supplied with 110 V, 50 c.p.s. through capacitor C4-14 used for phase shifting. Depending upon the phase (direct or opposite) of the voltage applied to the control winding the motor rotates clockwise or counter-clockwise with a speed determined by the value of the control voltage.

Automatic tracking motor M4-2 (Fig.119) rotates the main shaft of the distribution mechanism through worm and wheel ($i = 1/50$) and a cone differential ($i = 1/2$).

Rotation of the main shaft is imparted:

to the scale mechanism through one pair of spur gears ($i = 1$);

to the rotor of phase shifter C4-15;

to fine selsyn M4-3 through bevel gear pair ($i = 1$);

to coarse selsyn M4-4 through worm and wheel ($i = 1/20$);

to strobe delay potentiometer R4-21 through a bevel gear pair ($i = 50/43$).

Rotation to the main shaft may be imparted from the manual tracking handwheel with low and high speeds.

Low speed ($i = 1/10$) is used when tracking the target; the handwheel is set in the forward position.

High speed ($i = 1$) is used for rapid shifting of the sight; the handwheel is set in the backward position.

With such kinematic coupling one revolution of the main shaft corresponds to:

one revolution of the fine range scale;

1/20 of a revolution of the coarse range scale;

a turn of the strobe-delay potentiometer fine wiper through an angle equal approximately to $\frac{360^{\circ} \times 50}{43} = 418.6^{\circ}$;

a turn of the strobe-delay potentiometer coarse wiper through an angle equal approximately to 18°;

one revolution of the phase shifter rotor;

one revolution of the fine transmitting selsyn;

1/20 of a revolution of the coarse transmitting selsyn.

Scale Mechanism

The scale mechanism incorporates two scales (coarse and fine) connected with the main shaft. The main shaft rotation is imparted to the scale mechanism through a pair of spur gears (i = 1). The scales are graduated discs. The fine scale division value is 10 m., the coarse scale division value is 1000 m.

The range is read visually through an inspection port. The scale can be rotated either manually with the help of the range handwheel situated on the front panel of the unit or automatically by means of range tracking system. For this purpose switch MANUAL - AUTOMATIC should be set accordingly.

6. AUTOMATIC RANGE FINDER UNIT

The automatic range finder unit (Figs 121, 122 and 123, see Album) consists of a strobe forming channel (V7-1, V7-2, V7-3A, V7-3B, V7-4 and V7-5), a video amplifier channel (V7-8, V7-7, V7-6), an error signal discriminator (V7-17), a D.C. amplifier channel (V7-16 and V7-15), a converter (Q7-1) and an A.C. amplifier channel and AGC circuit (V7-13, V7-14, V7-11, V7-9, V7-10).

To make the automatic range finder operative it is supplied with the following pulses: the very narrow gate pulse from the range and very narrow gate indicator, video signals from the range channel amplifier of the receiving system and the gated video signal from the automatic tracking channel amplifier unit.

Split Gate Forming Channel

The very narrow gate pulse from connector Zw7-3 is furnished through the delay line (delay value is 0.6 microsec.) to the control grids of valves V7-1 and V7-2, type 6P9 (split gate forming stages).

In normal state valve V7-1 is almost cut off by a positive voltage of +8 V applied to the cathode from divider R7-6, R7-3 and R7-4. Valve V7-2 is cut off by the positive voltage applied to the cathode from divider R7-12, R7-9, R7-10.

Capacitors C7-3 and C7-16 are charged to the value of the plate voltage of valves V7-1 and V7-2 (about 220 V). The very narrow gate pulse impressed on the valve grids triggers these valves for a short period of time, thus discharging capacitors C7-3 and C7-16. As a result damped sine-wave oscillations are developed across circuits K7-1 and K7-2 which are formed by inductances L7-1 and L7-11 respectively and equivalent capacitances containing the wiring capacitance, the inter-turn capacitance of the coils and the capacitance of the valves. Inductances L7-1 and L7-11 are selected so as to ensure 0.6 microsec. duration of the first negative pulse. During the positive half-wave of the oscillations the damping diodes of valve V7-3 (6H6S) shunt the circuits and the oscillations are stopped.

Before the pulses from circuits K7-1 and K7-2 are applied to the control grid valves V7-4 and V7-5 (6P9) of the forming stages are on. The negative pulse coming from circuit K7-1 to the control grid of valve V7-4 cuts it off and a square positive pulse, i.e. the early gate of 0.6 microsec. duration having an amplitude of 55 V, is formed on the left-hand plate of error signal discriminator V7-17 (6H6S).

Similarly in 0.6 microsec. valve V7-5 develops the late gate of 0.6 microsec. duration on the right-hand plate of the discriminator. The split gate pulses are delayed for 0.6 microsec. in relation to each other, therefore, the end of the early gate coincides with the beginning of the late gate (Fig.124).

Video Amplifier Channel

The video amplifier is comprised of two amplification stages using valves V7-8B and V7-7 (Fig.123), a D.C. restorer stage (V7-8A) and a cathode follower (V7-6).

Positive video signals of about 2 V amplitude are furnished from the amplifier of the receiver range channel to the grid of the first valve of video amplifier V7-8B (6N8S) through connector Zw7-4. This valve operates with current negative feedback, since its cathode circuit is provided with resistors R7-35 R7-36.

The amplified negative voltage pulse from the plate of valve V7-8B is applied through coupling capacitor C7-21 to the control grid of the second video amplifier stage V7-7 (6P9). The plate circuit of valve V7-7 is fed with a stabilized voltage of +105 V from stabilovolt V7-12 (SG3S).

The second video amplifier stage simultaneously performs the function of a limiter clipping the signals applied to the error signal discriminator.

In the absence of video pulses valve V7-7 is conducting because the grid and cathode potentials are equal in value. In this case the value of the plate voltage is about +50 V. When the grid is supplied with the negative signal from the plate of valve V7-8B, valve V7-7 is cut off and the voltage on its plate becomes equal to +105 V. Thus the voltage drop on the plate of valve V7-7 makes up not more than 55 V. Therefore, the value of the pulse taken from the valve plate and applied to cathode follower V7-6 (6P9) cannot in all events exceed 55 V.

The grid circuit of valve V7-6 is provided with a D.C. restorer (the left half of valve V7-8) which operates as follows:

The grid and plate of the left half of valve V7-8 are connected together (diode connection). While video signals pass a negative charge is developed on the left-hand plate of capacitor C7-20. Upon cessation of the pulse the cathode of the left half of valve V7-8 obtains negative potential relative to the plate and the valve is on. Capacitor C7-20 rapidly discharges through valves V7-8 and V7-7. Thus at the end of every video signal zero level is restored on the grid of valve V7-6.

From cathode follower load R7-25 the positive video pulse is applied to the discriminator plates through resistors R7-89 and R7-90.

With the receiver AGC switched on, the normal signal level at the output of valve V7-6 should make up approximately 40 V. The amplification factor of the automatic range finder video amplifier is regulated by variable resistor R7-36 placed in the cathode circuit of valve V7-8B.

The resistor shaft R7-36 is brought out to the front panel of the automatic range finder unit and is marked FEEDBACK.

Error Signal Discriminator

The error signal discriminator employs valve V7-17 (6H6S) and serves as a time discriminator producing the error signal, the value and sign of which depend upon the time difference between the arrival of strobe pulses and the signal.

The main function of the discriminator is to separate the echo signal of the target being tracked from all the signals arriving from the receiver range channel with the help of two strobes and to divide the separated signal into two parts adjacent in time. Moreover, two diodes which function as a signal separator, are used as detectors, converting video pulses into D.C. voltage.

The discriminator plates are supplied with positive strobes from the plates of valves V7-4 and V7-5 and with video signals from cathode follower V7-6.

In the absence of strobes the positive voltage (of about +55 V) fed to the cathodes of valve V7-17 from divider R7-88, R7-86 and R7-85 keeps the discriminator cut off at the maximum value of the video signal.

The positive strobes coming to the plates of valve V7-17 trigger in succession the left- and right-hand diodes of the discriminator for 0.6 microsec. In this case capacitor C7-40 is charged with the current of the left-hand diode due to the action of part of the signal falling on the first strobe, while capacitor C7-41 is charged with that of the right-hand diode due to the action of part of the signal falling on the second strobe. The charges developed on these capacitors are approximately proportionate to the values of the appropriate parts of the signal. The voltage difference on the capacitors is used as an error voltage.

If the strobes are located in symmetry with the target echo signal, then the echo pulse is aligned with the electronic markers on the range indicators.

D.C. Amplifier Channel

The D.C. amplifier employs valves V7-16 (6N9S) and V7-15 (6N8S). To increase stability of the amplifier operation use is made of a balance circuit with high resistance R7-84 placed in the cathode circuit of valve V7-16. This cathode resistor does not affect the value of the error signal since with an increase of voltage on the grid of the valve right half the grid voltage of the valve left half decreases and the total cathode current does not change. However, any other change in voltages (plate voltage, valve filament voltage) causing a change of the valve total current is stabilized by high cathode resistance R7-84 due to negative feedback.

Besides, to increase stability of the stage operation the filament voltage of the D.C. amplifier valves (V7-15 and V7-16) is taken from the separate winding of transformer Tr7-4.

Error voltage is applied to the amplifier grids from the discriminator output through smoothing filters (R7-87 and C7-39, R7-95 and C7-38).

The stage amplification factor is approximately equal to 50. From the amplifier plates the error voltage is applied to cathode follower V7-15 (6N8S) through integrating circuits (R7-82, R7-83, C7-37 and R7-73, R7-74, C7-36). The integrating circuits enable the system to memorize as it were the speed essential for accurate tracking of fading signals. When the signal vanishes the current in the discriminator sharply decreases, but the error signal changes with large time constant of the integrating circuit memorizing the last speed value.

Placed between the cathode followers and converter Q7-1 are differentiating circuits R7-71, C7-35, R7-72, C7-34 and resistor R7-68. The error voltage applied to converter Q7-1 is developed across resistor R7-68.

In the steady state with constant error signal the differentiating circuits constitute a conventional voltage divider employing resistors R7-71, R7-72, and R7-68. A sharp change of the error signal is transmitted through capacitors C7-35 and C7-34 to load R7-68 thus ensuring rapid action of the follow-up system.

The error signal forming circuit is regulated by four potentiometers R7-86 BIAS, R7-17 BALANCE-3, R7-93 BALANCE-1, R7-80 BALANCE-2, the shafts of which are brought out to the front panel of the unit.

Potentiometer R7-86 BIAS is set in such a way that the error signal discriminator is triggered only by the peaks of strobes. Strobe amplitudes are set equal by potentiometer R7-17 BALANCE-3. The discriminator detecting circuits are balanced by potentiometer R7-93 BALANCE-1. The D.C. amplifier is balanced by potentiometer R7-80 BALANCE-2.

Monitoring jack G7-10 is intended for observing the signals applied from the video amplifier to the discriminator, while monitoring jack G7-9 for observing the passage of the selected signal through the discriminator.

.../Converter

Converter

The error signal should not be greatly amplified at D.C. because of instability of D.C. amplifiers, therefore, conversion of D.C. into A.C. is employed in the circuit.

Preamplification of the error signal at D.C. after the discriminator is found necessary to further integration and differentiation of the D.C. error signal as well as to improve the relationship between the error signal and the unbalance voltage of the converter circuit. The unbalance voltage appears due to spread of parameters of the copper-oxide and other elements of the converter circuit.

The converter is a bridge (Fig.125) composed of non-linear resistors, one diagonal of which is fed with a voltage of 50 c.p.s., whereas the other, into which the primary winding of transformer Tr7-3 is connected, produces an error signal voltage of 50 c.p.s.

With the potentials in points A and A_1 equal, when the error signal voltage is zero circuit A, R_1, R_2, R_3, A_1, is de-energized. In the presence of potential difference between points A and A_1 the above circuit conducts current whose direction is determined by the higher potential (A or A_1). The current flow in this circuit causes voltage drop U_2 across resistor R_2 whose value and polarity are determined by the error signal voltage. Voltage U_2 is impressed on both bridge diagonals through the primary winding of transformer Tr7-3 and resistors R_5 and R_6.

The circuit points a_1 and b_1 are fed with a voltage of 50 c.p.s. The divider mid-point B is connected through resistor R_2 with mid-point B_1 of the primary winding of transformer Tr7-3.

The converter circuit may be found under two following conditions:

no error signal voltage applied (the bridge is balanced);

error signal voltage applied (the bridge is unbalanced).

In the absence of the error signal only A.C. voltage U_3 is applied to bridge diagonal $a_1 - b_1$ and current passes through elements Q_2 and Q_1 or

through Q_4 and Q_3 depending upon polarity of voltage U_3.

Suppose polarity of voltage U_3 is like that shown in Fig.125. In this case elements Q_1 and Q_2 conduct current. By the action of the potential difference between points EB current will flow in direction $E-b_1-c_1-B_1-R_2-B$. By the action of the potential difference between points BE_1 current will flow in direction $B-R_2-B_1-c_1-a_1-E_1$. The half of the primary winding connected between points c_1-B_1 takes currents equal in magnitude but opposite in sign, and the difference current is zero.

In case of negative polarity voltage U_3 is applied through elements Q_4 and Q_3 and the current flowing through the half of the primary winding connected between points B_1-d_1 is zero as well.

Fig.125 is a representation of simplified characteristics of the elements and voltage charts explaining operation of the converter for the case considered above.

In the presence of the error signal the elements (A.C. element excluded) are fed with D.C. voltage whose polarity is determined by the sign, while the value by the error voltage value.

Suppose polarity of voltage U_2 is such that potential of points c_1 and d_1 is greater than that of points a_1 and b_1. Polarity of voltage U_3 is indicated in Fig.125. Now the operating conditions of element Q_2 are other than those of element Q_1.

Voltage U_2 will shift the operating point of element Q_2 towards negative values; the voltage cut-off angle will decrease and so will the current flowing through element Q_2. Voltage U_2 will shift the operating point of element Q_1 towards positive values; the cut-off angle of voltage U_3 will increase and so will the current flowing through element Q_1.

The value of the current flowing through the first half of the transformer primary winding is determined by the difference of currents passing through elements Q_1 and Q_2. The greater voltage U_2, the greater the difference.

When voltage U_3 has reversed polarity elements Q_4 and Q_3 are conducting. In this case the current flowing through element Q_3 is greater than that flowing through element Q_4 and the direction of the difference current through the second portion of the transformer primary winding is determined by current I_{Q_3} (Fig.125).

Induced in the secondary circuit of transformer Tr7-3 is an A.C. voltage of 50 c.p.s. whose amplitude is proportional to the value of the error signal and whose phase changes by 180° when polarity of voltage U_2 is reversed.

A.C. Amplifier Channel and AGC Circuit

The error signal A.C. voltage is amplified by a three stage amplifier feeding the control winding of the automatic tracking motor.

The first amplifier stage, i.e. a voltage amplifier based on a transformer with adjustable amplification factor is valve V7-13 of the 6K3 type (Fig.123). The signal at the discriminator output depends not only upon the value of time error between the strobes and the signal, but also upon the video signal amplitude which within the automatic tracking range 0.5 - 35 km. changes approximately 1.5 times. The stage gain is automatically controlled by changing the bias on the control grid, thus ensuring constancy of the common amplification factor of the automatic range finder follow-up system in range.

The bias voltage is developed by detecting in the stage using valve V7-14, (type 6N8S, connected as a diode) the negative video signal coming from the automatic tracking channel amplifier unit. By potentiometer R7-63 (automatic gain control) with normal signal and automatic gain control on, the bias value of valve V7-13 is set so, that the current as measured by instrument Pp7-1, located on the front panel of the automatic range finder unit, amounts to 5 to 6 mA.

Transformers Tr7-3 and Tr7-2 are shunted by resistors R7-65, R7-57 and R7-56 to increase stability of the amplifier operation. Capacitors C7-33,

C7-43 and C7-29, shunting the secondary windings of transformers Tr7-3 and Tr7-2, improve the A.C. voltage curve. With the help of potentiometer R7-56 (AMPLIFICATION) the automatic system is amplified to such a degree at which the system is set after two or three oscillations. To increase stability of the stage operation the screen grid of valve V7-13 is fed with a stabilized voltage of +105 V from stabilovolt V7-12.

The penultimate and final stages of the A.C. amplifier are based on a self-balance inverter circuit using valves V7-11 (6N8S), V7-10 (6N3S) and V7-9 (6P3S).

Inverter stage V7-11 makes it possible (without a special transformer) to obtain two A.C. voltages equal in value and 180° out of phase to feed the push-pull output stage. The A.C. voltage from the plate of the right-hand triode of valve V7-11 is passed to divider R7-47, R7-46, R7-45, R7-44 and to the control grid of valve V7-9 through capacitor C7-27. Part of the voltage from the divider is applied to the grid of the left-hand triode of valve V7-11 which changes the voltage phase. From the plate of the left-hand triode the voltage is impressed on the control grid of valve V7-10.

The self-balance inverter circuit is similar to the ordinary circuit except that it has balancing resistor R7-44. With different voltages on the control grids of valve V7-9 and V7-10 a voltage drop is developed across resistor R7-44 which is applied to the left-hand triode of valve V7-11 and which restores the circuit balance.

Transformer Tr7-1 is designed for matching the low-resistance of the motor control winding with the amplifier internal resistance.

Negative feedback required to decrease the amplifier output resistance is applied from the output of the push-pull amplifier to the input of valve V7-11. The negative feedback circuit is formed by resistors R7-54 and R7-55.

To facilitate the operator's work a receiver manual control knob marked AMPLIFICATION (variable resistor R7-99) is provided on the front panel of the automatic range finder unit.

Chapter 6

PLAN-POSITION INDICATOR SYSTEM AND POWER PACKS OF RANGE MEASURING AND PLAN-POSITION INDICATOR SYSTEM

A. PLAN-POSITION INDICATOR SYSTEM

1. GENERAL

The plan-position indicator system serves to detect and observe targets appearing in the region being scanned, as well as to roughly determine their coordinates.

The plan-position indicator system consists of a P.P.I. unit, a P.P.I. transmitting selsyn installed in the antenna pedestal.

The P.P.I. system is fed from the power pack common both for the range measuring system and the P.P.I. system.

Some elements of the P.P.I. unit (transformers Tr9-4, Tr9-5 and capacitor C9-7) are located in the power pack of the range measuring unit.

The P.P.I. unit is designed for shaping saw-tooth current pulses, which form a radial sweep on the indicator screen, voltage pulses gating the forward travel of the sweep and range marker voltage pulses forming the electronic range markers on the sweep.

The formation of the above pulses starts the moment the transmitter is triggered, because the operation of the P.P.I. unit is synchronized by the same trigger pulses furnished from the range unit which are also used for triggering the transmitter.

.../The P.P.I.

The P.P.I. unit accommodates an indicator which utilizes a cathode ray tube with magnetic control and a long-persistence screen. On the screen of the tube the operator can observe signals returned from the targets in the region being scanned. The target echoes on the screen enable the operator to determine two coordinates of a target in space: slant range and azimuth.

The target elevation cannot be read directly off the plan-position indicator. It may be determined by the reading of the elevation coarse indicator of the automatic tracking unit. For this purpose readings should be taken at the moment the target echo brightness on the P.P.I. screen is at maximum.

The sweep on the indicator screen is displayed as a straight bright radial trace which starts at the centre at the moment the pulse is fired by the transmitter and ends at the screen edge.

The slant range of the target is determined with the help of range markers displayed in the form of bright spots generated on the radial sweep. The distance between the markers equals 10 km. of the slant range.

When the antenna is rotated in azimuth the radial sweep rotates about the centre of the screen in step with the antenna: one revolution of the sweep corresponds to one revolution of the antenna. Provided that the station on the site is accurately oriented the position of the sweep on the tube screen relative to the azimuth scale calibrated on the edge of the disc arranged in front of the screen corresponds to the true azimuth of the antenna electrical axis. In this case the position of the station on the ground corresponds to the central point of the screen.

The signals returned from the target amplified in the receiver system and in appropriate stages of the P.P.I. unit are applied as positive voltage pulses to the control electrode of the indicator tube. Therefore at the moment the target echo is picked up, the brightness of the corresponding spot on the sweep trace increases. The pulses returned from the given

.../target arrive

target arrive after every transmitter direct pulse; they arrive all the time while the target is in the scanning region by the rotating antenna. The target is high-lighted on the indicator screen as echo-arc, the angular size of which depends upon the width of the radiation pattern, the flare angle between the maximums of the radiation pattern and the target angular size. According to this the angular size of the echo-arc showing the same target may change within a certain range as the antenna is lifted. For point targets (the angular size of which is considerably smaller than the radiation pattern width) the angular size of the echo-arc is approximately equal to 1-30.

Placed in front of the indicator cathode-ray tube on the side of the front panel of the P.P.I. unit is a transparent disc of plexiglass with an azimuth scale, the division value of which equals 0-25.

The target azimuth is read off the scale at the instant when the radial sweep passes through the centre of the echo-arc.

The target range is determined by the position of the echo-arc relative to the range markers whose number on the indicator screen amounts to six (Fig.126).

During circular scanning the antenna speed in azimuth is 12 r.p.m.

At the radiation pattern width of 0-83 and the flare angle of 0-46 between the maximum of the radiation pattern, the antenna irradiates a point target during 0.1 sec. so that the bright echo mark on the screen without after-glow would be visible for only 0.1 sec. Therefore, in order to enable the operator to determine the azimuth and target range, a cathode-ray tube with a long-persistence screen is used in the P.P.I. unit. Such a screen being brightened for a short time by the pulse returned from the target preserves its gradually weakening glow for about 10 sec. This enables the operator to observe on the indicator screen the entire surrounding space within a portion of the region being scanned in elevation

and, as the antenna is lifted up, the entire region in elevation and to take the necessary readings.

Long persistence of the tube is caused by the use of a double-layer screen. The first layer nearest to the electronic beam produces bright blue glow due to bombardment by electrons. The second layer applied directly to the screen glass is excited by the glow of the first one, thereby producing weak yellow glow. The first layer stops glowing immediately upon cessation of the screen bombardment by electrons. The second layer glows about 10 sec. (after-glow).

To prevent short-time bright blue glow of the first layer from interfering with observation of weak yellow glow of the second layer, the indicator is provided with a yellow light-filter placed in front of the screen. The light-filter absorbing the blue glow of the first layer freely passes the yellow glow of the second layer.

When the radial sweep rotates on the indicator screen the range markers due to the screen persistence merge, thus forming a system of concentric circles which make it possible to read off the traget range at any azimuth.

The P.P.I. is supplied with strobe pulses that increase spot brightness on the indicator sweep trace. During rotation of the antenna and consequently of the sweep, the bright spot forms a circle. The radius of the circle corresponds to the distance to the target being tracked, which helps the operator quickly to find the target if it gets lost.

Displays seen at the beginning of the sweep trace are either near-by targets or clutters caused by partial penetration of transmitter direct pulse voltage to the receiver.

The P.P.I. unit operates similarly during sector scanning. In this case parts of the concentric circles formed by the range markers as well as target and near-by echoes are displayed on the indicator screen only in that azimuth sector in which the antenna oscillates. The scanning sector is selected by the operator.

To facilitate finding of the target by the position data the P.P.I. is provided with a transparent overlay having a data presentation grid, located on the side of the front panel. The sheet and the azimuth scale of the indicator are illuminated from the edge by lamps Z11-1 to Z11-4 whose brilliance is controlled by potentiometer R11-52. The potentiometer knobbed shaft is brought out to the front panel of the unit and is marked SCALE ILLUMINATION.

The transmitting selsyn (M32-5) of the P.P.I. system is mounted in the antenna pedestal and is coupled with the antenna through 1:1 gear ratio. The transmitting selsyn is connected electrically with selsyn-transformer M11-1 of the P.P.I. unit. The transmitting selsyn is a component of the P.P.I. selsyn drive for the deflecting coil rotation.

2. FUNCTIONAL DIAGRAM OF PLAN-POSITION INDICATOR SYSTEM

Fig.127 is a representation of a functional diagram of the P.P.I. system.

The P.P.I. system incorporates:

Trigger pulse conversion channel.

Sweep channel.

Gating pulse channel.

Range marker channel.

Signal channel.

P.P.I.

Deflecting coil rotation selsyn drive.

The trigger pulse conversion channel consists of a two-stage amplifier (V11-1) and a multivibrator (V11-2). The input of this channel is fed with 1.5 microsec. negative trigger pulses of 15 to 20 V amplitude from the range unit. These trigger pulses are also used for triggering the driver in the transmitting system.

.../Amplified by

Amplified by two amplifier stages (two triodes of valve V11-1) the negative trigger pulses synchronize the operation of multivibrator V11-2 which produces nearly square voltage pulses. To make the unit operative use is made of negative voltage pulses from the multivibrator taken from the plate of the right-hand triode of valve V11-2. Their duration can be adjusted in accordance with the required detection range (60 km.).

The multivibrator negative voltage pulses control the sweep and gating pulse channels synchronizing their operation.

The sweep channel consists of a sweep generator (the left-hand triode of valve V11-3) and a current amplifier (V11-4) with a clamping circuit (the right-hand triode of valve V11-3). In the channel the multivibrator negative voltage pulses are converted into saw-tooth pulses of the same duration which arrive at the cathode-ray tube deflecting coil.

In the gating pulse channel negative square gating pulses are taken off the cathode of the gating amplifier (the right-hand triode of valve V11-6) to make the P.P.I. tube conducting during forward travel of the sweep.

The channel operation is controlled by the negative voltage pulse from the multivibrator, therefore the beginning and duration of the negative gating pulse strictly coincide with those of the multivibrator negative voltage pulse.

Thus, the gating pulses coming to the cathode of the P.P.I. cathode-ray tube trigger the tube for a period of the sweep forward travel.

The range marker channel consists of a marker delay electron relay (V11-5) and a range marker forming stage (the left-hand triode of valve V11-6). It produces short-time positive pulses of 15 Kc/s frequency, which form range markers on the indicator screen.

To trigger the range marker channel use is made of crystal controlled negative voltage pulses of 15 Kc/s frequency applied from the range unit.

.../Positive range

Positive range markers converted in the channel and delayed for 40 microsec. are furnished to the control electrode of the tube through mixer V11-8. The range marker delay may be adjusted within limits 10 - 50 microsec.

In the signal channel the range markers are mixed with strobe pulses and video pulses.

Strobe pulses are applied to the mixer stage directly from the range unit.

The video signals coming from the output of the receiver range channel are limited and amplified in the video amplifier stage (the left-hand triode of valve V11-7). Connected to the output of the video amplifier is a D.C. restorer stage (the right-hand triode of valve V11-7) maintaining the low level of voltage on the grid of the left-hand triode of mixer V11-8 constant. Connection of such a stage prevents loss of weak signals which otherwise might be below the level of the mixer cut-off voltage.

The range markers, strobe pulses and video pulses across the cathode load of the mixer (V11-8) form a combination signal which while being applied to the tube control electrode increases brightness of the radial sweep in spots corresponding to range markers, strobe pulses and video signals.

The P.P.I. is a cathode-ray tube with magnetic focusing and beam deflection system.

The deflecting coil rotation selsyn drive serves to rotate the radial sweep on the tube screen. The selsyn drive consists of a transmitting selsyn (M32-5) installed in the antenna pedestal, a selsyn transformer (M11-1) connected through two pairs of gears with a two-phase motor rotating the coils (M11-2) and with the deflecting coil gear, a two-stage error voltage amplifier (V11-11 and V11-12). Selsyns M32-5 and M11-1 employ a selsyn-transformer circuit.

The selsyn drive produces error voltage which serves to rotate the deflecting coil of the plan-position indicator in synchronism with the

3. PLAN-POSITION INDICATOR UNIT

Key diagram of the P.P.I. unit is shown in Fig.128 (See Album), the front panel and the unit top view in Figs 129 and 130.

Trigger Pulse Conversion Channel

The trigger pulse conversion channel consists of a two-stage amplifier and a synchronized multivibrator whose function is to convert negative trigger pulses into negative square pulses of 400 microsec. duration, which corresponds to a distance of 60 km.

The trigger pulse amplifier employs valve V11-1 of the 6N8S type (Fig.128) and is intended for increasing the amplitude of the incoming trigger pulse to such a value as to ensure stable synchronization of the multivibrator (V11-2).

The negative trigger pulse from the range unit is applied through connector Zw11-3 of the P.P.I. unit to the grid of the left-hand triode of valve V11-1 operating at zero bias. From the plate of this triode an amplified positive pulse is taken which is furnished to the grid of the valve right-hand triode. In the absence of the pulse the right-hand triode of valve V11-1 is cut off by positive voltage on the cathode (+19 V) applied through contact 4 of connector Zw11-1 from the power pack of the range measuring and plan-position indicator systems.

The positive voltage pulse triggers the right-hand triode of valve V11-1 and causes the pulse of negative polarity to appear on its plate. This pulse is passed through isolating capacitor C11-4 to the grid of the left-hand triode of multivibrator V11-2 and synchronizes the latter.

Capacitor C11-4 has low capacitance value to decreaee the influence of the multivibrator circuits upon the amplifier stage operation.

The multivibrator is based on an autodyne circuit employing valve V11-2 (6N8S). Its diagram is similar to those multivibrators that are

.../used in

used in the range unit as voltage dividers (See Chapter 5). However, time constants of the grid circuits (coupling circuits) of the two triodes in the multivibrator sharply differ in value from each other. Due to rather a long time constant of the valve right-hand triode grid circuit, the cut-off period of the right-hand triode when free running (i.e. in the absence of synchronizing pulses) greatly exceeds that of the left-hand triode, and oscillation frequency in this mode of operation is approximately 70 c.p.s.

Due to the fact that the multivibrator operates in an autodyne circuit of low frequency oscillations, the danger of burning the tube screen which might be caused by the stationary electron beam in the absence of synchronizing pulses from the range unit is averted. In this case the screen will display not a stationary spot but a pulsating sweep of low intensity. Decrease of intensity and appearance of noticeable pulsation of the sweep indicate that synchronizing trigger pulses are not furnished from the range unit.

The synchronizing negative pulses arriving at the grid of the left-hand triode of the multivibrator valve cut off the triode much earlier than it would have occurred during self-oscillation mode of operation. As a result the oscillation period of the multivibrator during synchronization decreases some dozens of times and its frequency increases accordingly from 70 c/sec to 1875 c/sec.

To reliably cut off the conducting left-hand triode by the synchronizing pulse it is necessary that it should have a sufficient amplitude. This is obtained by preamplifying the synchronizing pulse in the two-stage amplifier. The cut-off of the multivibrator left-hand triode by the synchronizing pulse causes a positive voltage drop on its plate whose value is sufficient to trigger the right-hand triode of the multivibrator.

This results in a negative voltage drop on the plate of the right-hand triode; this drop is passed to the grid of the left-hand triode to ensure

.../the cut-off

the cut-off condition of the left-hand triode just after cessation of the negative synchronizing pulse.

Due to discharge of coupling capacitor C11-5 the grid voltage of the left-hand triode gradually rises. At the moment it reaches the cut-off voltage the circuit is returned to the initial position in an avalanche-like manner, the circuit remaining in this position until the next synchronizing pulse arrives. The multivibrator output voltage is taken from the plate of the right-hand triode of valve V11-2. The value of the output voltage drop is approximately -80 V.

The moment the trigger pulse is obtained from the range unit coincides with the beginning of the multivibrator negative pulse and the negative pulse duration is determined by the time constant of the left-hand triode grid circuit since this time corresponds to the cut-off period of the left-hand triode. The time constant of the grid circuit of the multivibrator left-hand triode is determined mainly by values of capacitor C11-5, resistor R11-53 and potentiometer R11-5 whose shaft is brought out to the front panel of the unit and is marked SWEEP RANGE. Turning this shaft will regulate the duration of the multivibrator negative pulse. In this case the negative pulse should be such as to ensure not more than six range markers on the sweep.

The multivibrator output-voltage synchronizes the operation of the sweep channel and the gating pulse channel.

Sweep Channel

The sweep channel is designed to produce saw-tooth current applied to the deflecting coil of the cathode-ray tube to obtain a radial sweep on the tube screen.

Since deflecting coil L11-2 possesses inductance and ohmic resistance, the ends of the deflecting coil are fed with voltage of flat-topped waveform to obtain current (of saw-tooth waveform) rising linearly.

.../The sweep

The sweep generator employs the left-hand triode of valve V11-3 (6N8S) and is designed for shaping voltage pulses of flat-topped waveform.

The sweep channel is synchronized by negative pulses from the multivibrator (V11-2) which while acting on the grid of the left-hand triode (valve V11-3) cuts off the latter (Fig.131). In this case after a voltage jump on the plate which results from the voltage drop across resistor R11-16 caused by the discharge current of capacitor C11-9 the output voltage of the generator begins rising exponentially. By varying resistance R11-16 it is possible to change the value of the initial jump and the waveform (tilt angle) of trapeziodal voltage at the sweep generator output.

The slotted shaft of potentiometer R11-16 is brought out to the front panel and is marked SWEEP LINEARITY.

Upon cessation of the negative pulse of the multivibrator voltage the left-hand triode of valve V11-3 is on and capacitor C11-9 begins discharging through the triode and resistor R11-16 to the initial state.

The sweep generator is fed with a stabilized voltage of +490 V which ensures the trapeziodal voltage amplitude sufficient to form the sweep of the required length on the indicator screen.

The current amplifier with a clamping circuit (Fig.132) converts trapeziodal voltage pulses into saw-tooth current pulses.

The current amplifier employs valve V11-4 (6P3S), whose cathode circuit is provided with deflecting coil L11-2 (Fig.128). The amplifier functions as a cathode follower.

The cathode follower has a low output resistance and therefore the charge time of the total capacitance, consisting of the coil distributed capacitance and the wiring capacitance connected in parallel with the coil, is small and the influence of the total capacitance on the initial rate of the sweep rise is minimum.

.../The trapeziodal

The trapeziodal voltage from the plate of the left-hand triode of valve V11-3 is fed through capacitor C11-10 to the control grid of valve V11-4. Besides, the control grid is fed from the power pack of the range measuring and plan-position indicator systems with a negative bias voltage of about -160 V through resistors R11-19 and R11-18. The voltage cuts off the valve for a period of the sweep retrace. The value of the bias voltage is adjusted by potentiometers R11-19 whose slotted shaft is brought out to the front panel of the unit and is marked SWEEP LENGTH.

Placed in the control grid circuit of valve V11-4 is a diode clamping circuit. Should there be no circuit, in the intervals between the incoming trapeziodal positive voltage pulses capacitor C11-10 would not discharge and an additional negative potential would be developed on the control grid of valve V11-4, the potential value being dependent upon the duration amplitude and form of the pulses arriving at the grid. Consequently, the value of this additional negative potential would vary when rotating the shafts of potentiometers R11-5 and R11-16. Such variation of the initial potential on the current amplifier control grid causes a change of its value, which results in the sweep length being changeable on the indicator screen.

The clamping diode circuit employs the right-hand triode of valve V11-3 (6N8S), the triode being connected in parallel with leak resistance R11-18 (Fig.132). The cathode of the triode is coupled to the control grid of valve V11-4 and the grid in turn is shorted to the plate, i.e. the triode is a one-way resistor ensuring rapid discharge of capacitor C11-10 during the sweep retrace. As the potential of the right-hand plate of capacitor C11-10 or, which is the same, the cathode potential of the right half of valve V11-3 is found to be lower than the grid potential, after the positive trapeziodal pulse has passed through, the valve will conduct and capacitor C11-10 will discharge through the valve before the next trapeziodal pulse arrives. Thus, the additional negative bias potential is cancelled out on the control grid of valve V11-4.

A change in the bias voltage of valve V11-4 causes a change in the position of the operating point on the valve characteristic curve. The trapeziodal pulse is clipped in the current amplifier on account of the lower bend of the valve characteristic, therefore the change of the bias causes a change in the current amplitude and, consequently, in the sweep length on the indicator screen. In this case its duration does not change, i.e. the number of range markers on it remains constant.

The negative voltage applied to the control grid of the current amplifier is sufficient for cutting off valve V11-4 for a period of the sweep retrace.

The oscillation process in the deflection coil circuit caused by a sharp decrease of the sweep current is of no importance as during the sweep retrace there is no electronic beam in the cathode-ray tube and this process ceases on the arrival of the next trigger pulse from the range unit.

Gate Pulse Channel

The gating pulse channel consists of one stage, i.e. a brightness intensifier, and serves to trigger the cathode-ray tube for a period of the sweep forward travel.

The brightness intensifier employs the right-hand triode of valve V11-6, type 6N8S (Fig.128) and is essentially a cathode follower whose cathode load is formed by resistor R11-36 and part of potentiometer R11-35.

The grid of valve V11-6B is connected to a +270-volt supply through resistor R11-32, whose resistance value is 4.7 megohms. The grid is fed with the negative pulse from the output of multivibrator V11-2 through coupling capacitor C11-18. The output voltage of the brightness intensifier is taken off the cathode load (R11-36 and R11-35) and is directly applied to the cathode of the cathode-ray tube.

Before the multivibrator negative pulse arrives the valve grid voltage is approximately zero and the valve handles the plate current. A voltage

.../drop developed

drop developed across the intensifier cathode load is found to be sufficient to fully cut off the indicator, therefore the indicator screen does not glow at the time.

The multivibrator negative pulse arrives, the valve is cut off and as a result the voltage, applied to the tube cathode from the intensifier cathode load, decreases. The decrease of the cathode potential of the cathode-ray tube causes the tube to conduct (indicator screen gating) for a period of the multivibrator negative pulse, i.e. for a period of the sweep forward travel. The voltage value on the tube cathode and, consequently, the brightness of the sweep trace can be controlled by potentiometer R11-35 whose shaft is brought out to the front panel of the unit and is marked BRIGHTNESS.

Range Marker Channel

The electronic marker channel consists of a marker delay electron relay and a range marker forming stage and is intended to obtain a train of short-duration pulses the space between which corresponds to 10 km. slant range.

To trigger the range marker channel use is made of negative pulses of short duration and 15 Kc/s frequency (which corresponds to 10 km. range) being furnished to the P.P.I. unit from the range unit.

These pulses arrive from the range unit not at the moment the transmitter is triggered, but 40 microsec. earlier, therefore to delay the pulses for 40 microsec. a marker delay electron relay is used. The oscillograms showing voltages in the range marker channel circuits are presented in Fig.133.

The marker delay electron relay employs valve V11-5, type 6N8S, (Fig.128). It is similar in design to the strobe width electron relay whose operation is described in Chapter 5.

Negative pulses of 15 Kc/s frequency are applied from pin 8 of connector Zw11-1 to the grid of the left-hand triode of valve V11-5 through isolating

.../capacitor C11-12.

capacitor C11-12. In the absence of trigger pulses the left-hand triode conducts because its grid is fed with a positive potential of +3.9 V from a voltage divider formed by resistors R11-21 and R11-22. The right-hand triode is cut off by a negative voltage of -34 V applied to pin 10 of connector Zw11-1 from the power pack of the range measuring and plan-position indicator systems.

With negative pulses applied to the grid of the left-hand triode the electron relay is turned over. As a result, negative voltage pulses whose duration depends upon the time constant of the discharge circuit of capacitor C11-13 composed mainly of capacitor C11-13 and resistor R11-23 are developed on the plate of the right-hand triode of valve V11-5. The duration of the negative pulses taken from the plate of the right-hand triode can be adjusted with the help of potentiometer R11-23 within 10 to 50 microsec. The trailing edge of these pulses triggers the range marker forming stage, which provides the required delay of the pulses.

The slotted shaft of potentiometer R11-23 is brought out to the front panel of the unit and is marked MARKER DELAY.

The range marker forming stage employs the left-hand triode of valve V11-6 (6N8S) and is a cathode follower. The cathode load of the follower is resistor R11-51.

In the absence of pulses from valve V11-5 the left-hand triode of valve V11-6 is cut off by positive cathode voltage taken off a voltage divider formed by resistors R11-28 and R11-51.

The negative square pulses taken off the plate of the right-hand triode of valve V11-5 are furnished to a differentiating circuit composed of capacitor C11-15 and resistor R11-62. The negative and positive pulses are passed from the differentiating circuit output to the grid of the left-hand triode of valve V11-6. In this case the negative pulses have no effect upon the cut-off valve, while the positive ones corresponding to the trailing edge of the negative square pulses make it conducting.

In the cathode of valve V11-6A, short positive voltage pulses of 15 Kc/s frequency are developed, which are used to form range markers (on the sweep) spaced from each other at a distance corresponding to 10 km. of slant range. These pulses are applied to the grid of the right-hand triode of mixer V11-8 from potentiometer R11-29 which is used to vary their amplitude and, consequently, the brightness of the range markers on the sweep.

The knobbed shaft of potentiometer R11-29 is brought out to the front panel on the unit and is marked BRIGHTNESS.

Signal Channel

The signal channel consists of a video amplifier, a D.C. restorer and a mixer.

The video amplifier employs the left-hand triode of valve V11-7 (6N8S). The negative video signals from the output of the receiver range channel are applied through pin 9 of connector Zw11-1 to the grid of the video amplifier operating at zero grid bias.

Due to comparatively low voltage of the plate supply (+120 V) obtained as a result of +270 volts dropping across decoupling resistors R11-37, R11-38 and R11-39, the valve cut-off voltage is approximately -7 V. The cut-off of the video amplifier plate current results in video signal voltage being clipped approximately at the noise level. This considerably improves the discrimination of weak signals since the amplitudes (brightness of images) of strong and weak signals are practically balanced.

The amplified and clipped video signals of positive polarity are applied to the grid of the left-hand triode of mixer V11-8 from the video amplifier plate through isolating capacitor C11-21.

The D.C. restorer employs the right-hand triode of valve V11-7 (6N8S) connected as a diode. It is designed to create D.C. initial potential on the grid of the mixer left-hand triode before arrival of every video signal.

The D.C. restorer plate and grid are earthed, while the cathode is connected to the grid of the left-hand triode of mixer V11-8 and the right-hand plate of capacitor C11-21.

On arrival of each positive video signal of the voltage taken off the video amplifier plate isolating capacitor C11-21 is additionally charged. Should there be no D.C. restorer the capacitor would discharge very slowly in time intervals between the video signals because of the presence of large resistance R11-43 (1 megohm) in its discharge circuit. Therefore, after the signal, returned from a cluster of ground objects or a group target, has passed through, the grid potential of the mixer left-hand triode would be found, for a comparatively long period of time, appreciably lower than its initial value, i.e. the valve operating point would be shifted to the left, to the section of the grid characteristic with reduced transconductance (Fig.134). Thus, the discrimination of weak signals following the long strong signals might be noticeably deteriorated.

The D.C. restorer ensures rapid discharge of isolating capacitor C11-21 (Fig.128) upon cessation of each video pulse through a low resistance of the conducting right-hand triode of valve V11-7. As a result each video pulse on the grid of the mixer left-hand triode starts from the same initial potential.

When the video pulse is coming to the mixer grid the D.C. restorer valve is cut off and has no effect on the mixer grid circuit.

The mixer employs valve V11-8 (6N8S) and is designed to produce a composite signal of positive polarity for the control electrode of the cathode-ray tube (V11-9).

The plates and cathodes of the mixer triode are interconnected, i.e. the mixer operates as two cathode followers with a common cathode load composed of resistor R11-44.

The grid of the mixer left-hand triode, as mentioned above, is fed with positive video pulses, whereas that of the right-hand triode with

range markers and strobe pulses of positive polarity as well. Thus a composite signal to be applied to the control electrode of the cathode-ray tube is obtained on the cathode load common to both triodes.

The leak resistance of the mixer left-hand triode is resistor R11-43. The leak resistance of the valve right-hand triode is resistance of a circuit composed of resistors R11-46 and R11-29 connected in parallel with resistors R11-45 and R11-47. Thus, the grids of both triodes of the mixer are earthed, therefore both triodes operate at negative bias equal in magnitude to the cathode potential.

The strobe pulses from the range unit (from pin 3 of connector Zw11-1) are furnished to the grid of the mixer right-hand triode through isolating capacitor C11-2, resistor R11-45 and potentiometer R11-47, which makes it possible to change the value of strobe pulse amplitudes and, consequently, the strobe brightness on the indicator sweep. The shaft of potentiometer R11-47 is brought out to the front panel of the unit, fitted with a knob and is marked STROBE BRIGHTNESS.

Resistor R11-46 placed in series with potentiometer R11-29 and resistor R11-45 in series with potentiometer R11-47 are decoupling resistors connected into the circuits supplying strobe pulses and range pulses to the grid of the mixer right-hand triode. These resistors make the regulation of the amplitude of strobe pulses and range markers on the mixer grid practically independent.

Plan-Position Indicator

Used as a plan-position indicator is cathode-ray tube V11-9, type 18LM35, with magnetic focusing and deflection of the beam.

A magnetic field to focus the electronic beam is induced by focusing coil L11-1 fitted on the tube neck.

The focusing coil is enclosed in a housing of soft steel the inner cylindrical wall of which is provided with a circular slot. Due to the slot the lines of force of the magnetic field set up by the coil cannot

close through the steel housing and pierce the space in which the tube neck is arranged.

The coil with the housing is so secured on the tube neck that it can be turned by means of two knobs 1 through a small angle about the two shafts set at right angles (Fig.130). This is necessary to bring the beginning of the radial sweep on the indicator screen in the centre.

For creating a magnetic field of the required intensity direct current is passed through the focusing coil. For this purpose the coil is connected in series with potentiometer R11-50 (Fig.128) to the +270-volt supply of stabilized voltage.

The value of current in the focusing coil is adjusted by potentiometer R11-50 whose knobbed shaft is brought out to the front panel of the unit and is marked FOCUS. By adjusting the current value by knob FOCUS a sharply outlined sweep can be obtained on the indicator screen.

Radial deflection of the electron beam from the tube axis is caused by a magnetic field perpendicular to the tube axis. This field is created by saw-tooth current flowing through deflecting coil L11-2.

The deflecting coil L11-2 is designed as two sections connected in series; the coil is placed inside a paper-bakelite cylinder and fixed on the neck of the cathode-ray tube in front of the focusing coil by means of three ball bearings.

Pressed on the deflection coil cylinder are two slip-rings connected with the coil leads. The slip-rings are fed with voltage from two brushes: one brush connected to the unit chassis, the other to the cathode of the current amplifier (V11-4), since the deflecting coil is the amplifier cathode load.

On the focusing coil side the deflecting coil cylinder mounts a gear coming in mesh with the gear of the selsyn-transformer (M11-1) of the P.P.I. unit. Therefore, rotation of the selsyn-transformer is imparted to the

.../deflecting coil,

deflecting coil, which causes a radial sweep to revolve on the indicator screen.

The deflecting coil and the cathode-ray tube are enclosed in a shield of permalloy to reduce influence of a magnetic field created by the supply circuit of motor M11-2 upon the magnetic field of the deflecting coil.

The control electrode of the tube is fed with strobe pulses, amplified video signals and range pulses. For a time of the sweep forward travel the cathode-ray tube is triggered by negative square pulses applied to the cathode of the tube from the right-hand triode of valve V11-6 (brightness intensifier).

Deflecting Coil Rotation Selsyn Drive

The selsyn drive rotating deflecting coil L11-2 incorporates: a transmitting selsyn (M32-5) of the P.P.I. unit, a selsyn transformer (M11-1), a two-phase induction motor (M11-2) rotating deflecting coils, a two-stage error voltage amplifier (valves V11-11 and V11-12).

The deflecting coil rotation selsyn drive serves to rotate a radial sweep on the screen of the P.P.I. in synchronism with the rotation of the radar antenna in azimuth.

Transmitting selsyn M32-5 (a selsyn of the SS-405 type) is placed in the antenna pedestal. The selsyn rotor is coupled through gearing 1:1 to the axle rotating the antenna in azimuth: the rotor winding is connected with 110 V, 50 c.p.s. A.C. mains. The stator windings of the selsyn are connected to those of selsyn-transformer M11-1. Alternating current flowing through the rotor winding creates a magnetic flux which varies sinusoidally in time with 50 c.p.s. frequency. This magnetic flux induces A.C. electromotive force in the stator windings.

Selsyn-transformer M11-1 (a selsyn of the SS-405 type) is located in the P.P.I. unit. It produces error voltage registering an error in matching the shafts of the selsyn-transformer and transmitting selsyn.

.../The selsyn-transformer

The selsyn-transformer rotor is coupled through gearing 1:1 to the deflecting coil of the cathode-ray tube and through gearing 1:25 to the shaft of electric motor M11-2.

Selsyn-transformer M11-1 operates as a single-phase transformer provided with three stationary primary windings and one movable secondary winding. Currents flowing through the stator windings of the selsyn-transformer induce a magnetic flux in the latter by the action of the transmitting selsyn voltage.

The mean square value of the voltage (error voltage) induced in the selsyn-transformer rotor winding depends upon the position assumed by its rotor shaft relative to the magnetic flux and, consequently, upon the position of the transmitting selsyn rotor shaft. When the shafts of the selsyn-transformer and transmitting selsyn are aligned the error voltage equals zero.

The error voltage is an A.C. voltage whose frequency equals the mains current frequency (50 c.p.s.) whereas the phase coincides with that of the mains or differs from it by 180° depending upon the sign of the mismatch angle between the shafts of the selsyn-transformer and the transmitting selsyn.

The error voltage is applied from the rotor winding of the selsyn-transformer to the error voltage amplifier (valves V11-11 and V11-12). The amplifier produces voltages controlling two-phase A.C. induction motor M11-2 (electric motor, type 2ASM-50/20V) the speed of which is proportional to the value of the error voltage and the direction of rotation is determined by the error voltage phase relative to the mains voltage.

The two-stage error voltage amplifier employs valves V11-11 (6Z8) and V11-12 (6P8S). The first stage (V11-11) is a resistor-coupled voltage amplifier with negative feedback; the second stage (V11-12) is an amplifier which matches the high resistance output of the first stage with the low input resistance of the field winding of electric motor M11-2.

Negative feedback voltage is applied to the input of the first amplifier from resistor R11-58 which is part of a voltage divider connected to the output of the second stage.

Due to negative feedback the amplifier amplification factor is dependent to a lesser degree upon changes in supply voltages and output load resistance, valve replacement and other factors.

The plate load of the second stage (valve V11-12) is step-down transformer Tr9-5 installed in the power pack of the range measuring system. The output voltage of this stage, taken off the secondary winding of transformer Tr9-5 is applied to one of the field windings of motor M11-2.

The second field winding of the motor is fed with voltage from step-down transformer Tr9-4 whose primary winding is connected to 110 V, 50 c.p.s. mains; placed in the circuit of this winding is capacitor C9-7 to shift the supply voltage in phase by 90° relative to the amplifier error voltage.

Transformer Tr9-4 with capacitor C9-7 is located in the same place as transformer Tr9-5.

When the antenna is turned, an error voltage is developed in the rotor winding of the selsyn-transformer. The amplified error voltage controls the operation of motor M11-2 coupled mechanically through a reduction gear to the selsyn-transformer rotor rotation shaft and the deflecting coil. At every moment the phase of the control error voltage is such as to make the selsyn-transformer rotor rotate decreasing the mismatch angle. The continuous rotation of the antenna in azimuth causes continuous generation of error voltage, therefore the deflecting coil and, consequently, the sweep on the tube screen rotates in synchronism with azimuth rotation of the antenna.

To monitor voltages and observe oscillograms the unit is provided with monitoring jacks connected to various points of the circuit and located on the unit chassis.

B. POWER PACKS OF RANGE-MEASURING AND PLAN-POSITION INDICATOR SYSTEMS

1. GENERAL

The plate and filament circuits as well as bias circuits of the valves in the range measuring system and plan-position indicator systems are supplied from two separate power packs: the power pack of the range measuring and plan-position indicator systems and the power pack of the range measuring system.

Used as a primary supply is 110 V, 427 c.p.s. mains.

The power packs are composed of rectifiers and separate transformer supplying the units, stages and separate elements of both units with required D.C. and A.C. voltages.

A block diagram of the power packs is presented in Fig.135.

2. POWER PACK OF RANGE-MEASURING AND PLAN-POSITION INDICATOR SYSTEMS

The power pack is composed of a +4800-volt half-wave rectifier, a -1700-volt half-wave rectifier and a +490-volt full-wave rectifier with a +270-volt stabilizer.

A key diagram of the unit is shown in Fig.136 (See Album), the front panel in Fig.137 and top view in Fig.138.

+4800-volt Rectifier

The +4800-volt rectifier produces voltage to feed the second plate of the cathode-ray tube of the P.P.I. unit. It consists of step-up transformer Tr5-3 (Fig.136) and kenotron V5-10 (W1-0.02/20). The ripples of the rectified voltage are smoothed by a filter composed of resistors R5-37 through R5-48 and capacitors C5-13 and C5-12.

To increase stability of the output voltage and to ensure discharge of the filter capacitors after the rectifier is off, a series combination of

.../twelve resistors

twelve resistors (R5-50 to R5-61) whose total resistance is 6.7 megohms is connected at the filter output.

-1700-volt Rectifier

The -1700-volt rectifier consists of step-up transformer Tr5-1 and kenotron V5-1 (2C2S). The ripples of the rectified voltage are smoothed by a filter comprised of resistors R5-1 through R5-4 and capacitors C5-1 - C5-3.

The rectifier positive pole is earthed, the negative one is connected through connector Zw5-1 to the range and very narrow gate indicator unit to feed the electrodes of the cathode-ray tube with -1700 volts.

Connected at the rectifier output is a divider formed by resistors R5-5 through R5-18, R5-64; this divider supplies the following voltages:

-160 volts applied to the control grid of the current amplifier valve in the P.P.I. unit (through pin 6 of connector Zw5-3);

-90 volts applied to the selector stage of the range and very narrow gate indicator unit (through pin 15 of connector Zw5-2);

-34 volts applied to the valve grids of the gating width electron relay, the strobe-pulse width electron relay, to the control grid of the trigger selector valve (all these components are located in the range unit) and to the valve grid of the marker delay electron relay of the P.P.I. unit (through pin 13 of connector Zw5-3 and pin 14 of connector Zw5-2);

-28 volts fed to the range and very narrow gate indicator unit to the valve grids of the very narrow gate and electronic marker blocking oscillators (through pin 12 of connector Zw5-2);

-5 volts applied to the control grid of the trigger selector valve in the range unit (through pin 2 of connector Zw5-2).

The voltage of -28 V is adjusted by variable resistor R5-18 whose slotted shaft is brought out to the front panel of the unit and is marked BIAS.

.../Taken from

Taken from windings of transformer Tr5-1 are filament voltages of valves and cathode-ray tubes of the range and very narrow gate indicator unit, range measuring unit, power pack of the range measuring and P.P.I. systems, range unit and P.P.I. unit.

+490-volt Rectifier with +270-volt Stabilizer

The rectifier supplies a stabilized voltage of +270 V to the plate circuits of almost all valves of the range measuring and plan-position indicator systems but the very narrow gate blocking oscillator, the first and second electric marker blocking oscillators, the sweep centring circuit of the range and very narrow gate indicator unit, the sweep generator of the P.P.I. unit which are fed with +490 volts from the output of the rectifier filter, and a push-pull output stage of the 50 c.p.s. amplifier of the automatic range finder which is fed from +450-volt rectifier located in the power pack of the range measuring system.

The rectifier consists of kenotrons V5-2, V5-3, V5-11 (5C3S), step-up transformer Tr5-2 and a voltage stabilizer (V5-4 through V5-9).

The ripples of the rectified voltage are smoothed by a filter with a capacitive input composed of choke D15-1 and capacitors C5-6 and C5-7.

The rectified voltage of +490 V is applied from the filter output to the range and very narrow gate indicator unit for feeding the blocking oscillators and sweep centring circuit, to the P.P.I. unit for feeding the sweep generator stage and to the voltage stabilizer, whose simplified diagram is presented in Fig.139.

A parallel combination of four valves (V5-4 through V5-7), type GU-50, performing the function of adjustable resistors, is connected in series with the load. The resistance inserted by the valves in this circuit is regulated by control valve V5-8 (pentode of the 6P9 type) so as to maintain a constant voltage of +270 V at the voltage stabilizer output.

The control grid of valve V5-8 is fed with a portion of the voltage stabilizer output from the slider of potentiometer R5-33 which is placed in the circuit of a divider formed by resistors R5-32, R5-33, R5-34. Thus, every variation of the stabilizer output voltage is accompanied by variation of the potential on the control grid of valve V5-8.

When the stabilizer output voltage increases for some reason or other (change in mains voltage load current, etc.) the grid potential of valve V5-8 rises, which results in a reduced valve plate potential. This causes an increase of the negative potential of control grids of valves V5-4 through V5-7 and makes the D.C. plate resistance of these valves rise. In this case the stabilizer input voltage of 490 volts is so redistributed, that voltage increases on the plate - cathode section of valves V5-4 through V5-7, and decreases nearly to the rated value across the load.

With the output voltage decreased, the plate potential of valve V5-8 increases, while the D.C. plate resistance of valves V5-4 through V5-7 decreases. As a result the value of the output voltage approximates the initial rated value.

The screen grid and cathode of control valve V5-8 are fed with voltages from a divider connected in parallel with the stabilizer output. This divider consists of resistors R5-31, R5-29 and stabilovolt V5-9, type SG3S, which maintains a D.C. voltage of +105 V (relative to earth) on the cathode of valve V5-8. This is done to enable a considerable portion (over one third) of voltage to be applied from the stabilizer output to the grid of valve V5-8 thereby preserving normal operation of the valve (with small negative grid bias). With the selected circuit any variation of the stabilizer output voltage is impressed on the valve grid with transmission factor of about 0.3. Should stabilovolt V5-9 not be used such transmission factor could not be obtained as the amplifier valves cannot normally function with great positive grid bias voltages.

Capacitor C5-9 connected between the control grid of valve V5-8 and the stabilizer output, increases the efficiency of the circuit in stabilizing quick oscillations and ripples of the output voltage. For A.C. component of the output voltage of some dozens of cycles per second and higher capacitor C5-9 is rather a low resistance as compared with that of the divider upper arm. Therefore, the output voltage A.C. component is passed in full to the grid of the control valve.

Capacitor C5-10 connected in parallel with valve V5-9 improves stabilizing action of the valve at rapid changes of the voltage. Besides, capacitors C5-10 and C5-11 make the circuit operation more stable protecting it against self-oscillations at high frequencies.

The stabilizer output voltage is regulated by means of potentiometer R5-33 whose knobbed shaft is brought out to the front panel and is marked STABILIZED VOLTAGE. Should the position of the potentiometer slider be slightly changed the output voltage would largely vary, which should be kept in mind when regulating the voltage.

Divider R5-35 and R5-36 (Fig.136) connected at the output of the voltage stabilizer feeds a voltage of +19 V to the trigger pulse amplifier of the P.P.I. unit.

The front panel of the power pack of the range measuring and plan-position indicator systems is provided with voltmeter Pp5-1 (type M-52) by means of which the value of the stabilized voltage is checked.

The power packs are fed with 110 V, 50 c.p.s. and 110 V, 427 c.p.s. through three switches (W5-1, W5-2, W5-3) located on the front panel of the unit (See Fig.137).

With rotary switch W5-1 on (Fig.136) 110 V, 427 c.p.s. are applied to the primary winding of transformer Tr5-1 and to the input of the range measuring system power pack. In this case heaters of valves in all units are energised, 1700-volt rectifier of the range measuring and plan-position

indicator systems and +450-volt and -210-volt rectifiers of the power pack of the range measuring system.

The application of voltage to the power packs is indicated by means of lamp V5-12 located on the front panel of the power pack.

Switch W5-2 turns on a stabilized voltage of +270 V, a voltage of 110 V, 50 c.p.s. being simultaneously applied to transformer Tr9-3 of the range measuring system power pack. Switch W5-3 energizes the +4800-volt rectifier of the power pack of the range measuring and plan-position indicator systems.

The front panel of this power pack carries four fuses: B5-1 for 10A in the 110 V, 427 c.p.s. common circuit of the pack, B5-2 for 6A in the circuit of valve filament transformer Tr5-1, B5-3 for 6A in +490-volt rectifier circuit and B5-4 for 2A in +4800-volt rectifier circuit.

3. POWER PACK OF RANGE-MEASURING SYSTEM

The power pack of the range measuring system (See Fig.140, Album) incorporates a +450-volt full-wave rectifier and a -210-volt full-wave stabilized voltage rectifier. Besides, the power pack accommodates step-down transformer Tr9-4 feeding the uncontrolled winding of motor M11-2 of the P.P.I. unit with 20 volts, 50 c.p.s., output transformer Tr9-5 of the error voltage amplifier of the P.P.I. unit with transformation ratio 10:1, feeding voltage to the control winding of motor M11-2 and transformer Tr9-3 with transformation ratio 1:1 from secondary winding of which voltage is taken to motor M4-2 of the range mechanism unit and to transformer Tr7-4 located in the automatic range finder unit. Transformer Tr9-3 isolates 110 V, 50 c.p.s. circuit from the earthed winding of motor M4-2.

The front panel of the power pack is shown in Fig.141, while its top view in Fig.142.

+450-volt Rectifier

The rectifier is designed to supply the plate circuits of the output stage of the 50 c.p.s. error voltage amplifier of the automatic range finder and incorporates transformer Tr9-1 (Fig.140) and kenotron V9-1 (5C3S).

Taken from the filament winding of transformer Tr9-1 (leads 6 and 7) is a voltage of 6.3, 427 c.p.s. to heat all the valves of the automatic range finder, with the exception of a filament voltage of 6.3 V, 50 c.p.s. for the D.C. current amplifier valves which are fed from separate transformer Tr7-4 situated in the automatic range finder unit.

The rectified voltage ripples are smoothed by a filter composed of choke D19-1 and capacitors C9-1 and C9-2.

A voltage of +450 V from the filter output is applied to the automatic range finder unit through pin 9 of connector Zw9-1.

-210-volt Stabilized Voltage Rectifier

The rectifier is intended to supply a stabilized voltage of -210 V to the strobe delay circuit of the range unit. The rectifier consists of transformer Tr9-2 and kenotron V9-5 (5C3S).

The rectified voltage ripples are smoothed by a filter composed of capacitors C9-3, C9-4 and choke D19-2.

The voltage is stabilized by means of two stabilovolts V9-3 and V9-4 (SG3S) connected in series.

Load resistor R9-2 is so designed that a current of about 12 mA passes through the stabilovolts and a voltage of -210 V is set on the cathode of valve V9-4 (pin 2). An increase or decrease of the supply voltage causes a change in the current flowing through the stabilovolts but the characteristic of the gas discharge in them is such that the voltage across the stabilovolts remains constant.

Capacitors C9-5, C9-6 are connected in parallel with stabilovolts V9-3 and V9-4 and serve to improve stabilization when there are pulse changes in the load or voltage.

The front panel of the power pack (Fig.141) carries four 5A fuses: two fuses (B9-1 and B9-2) in the 110 V, 427 c.p.s. circuit, the other two (B9-3 and B9-4) in the 110 V, 50 c.p.s. circuit, and a clock.

Chapter 7

ANTENNA POSITIONING SYSTEM

1. GENERAL

The antenna positioning system serves to control the antenna rotation in azimuth and elevation.

The system permits the following three modes of operation to be used, manual control, automatic circular or sector scanning and automatic target tracking in azimuth and elevation.

Furthermore, the antenna can be remotely controlled from the PUAZO-6.

In all modes of operation the antenna is rotated in azimuth and elevation by two drive motors which are included in the azimuth and elevation follow-up selsyn drive.

In each mode of operation the selsyn drive is controlled differently.

During manual control the antenna is turned due to manual rotation of the antenna control unit handwheels.

During automatic circular scanning the antenna is automatically rotated clockwise (as viewed from the top) with a speed of 12 r.p.m.

Automatic circular scanning may take place at any given fixed elevation or with elevation coverage.

During automatic circular scanning with elevation coverage the antenna rotating in azimuth simultaneously makes automatically periodic oscillations in the assigned sector in elevation. For eight revolutions in azimuth the antenna is lifted up by 2-00 and for one (the ninth) revolution is lowered down to the initial position.

During automatic sector scanning the antenna automatically oscillates in azimuth within a sector of 4-00 to 9-00 at a rate of 30 complete oscillations per minute. The scan sector may be set at will within limits of 00-00 to 60-00.

Simultaneously with oscillations in azimuth the antenna can

oscillate in elevation within 1-70 to 2-10 at the antenna initial positions in elevation from 00-00 to 12-50. For four oscillations in azimuth the antenna is lifted up and for one (the fifth) oscillation is lowered down.

During automatic target tracking the antenna is automatically rotated in azimuth and elevation following the changes in the target azimuth and elevation.

The antenna positioning system is comprised of the following components and units: an automatic tracking unit, an elevation and azimuth tracking unit, an antenna control unit, an antenna pedestal, a power pack of the drive motor field windings, azimuth and elevation drive motors, a reference voltage generator (GON) and azimuth and elevation amplidynes.

As was mentioned above at any mode of operation the antenna is rotated in azimuth and elevation by means of an azimuth and elevation drive D.C. motor located in the antenna pedestal.

The armature windings of the drive motors are supplied from the azimuth and elevation amplidynes. The magnitude and polarity of these voltages, which determine the speed and direction of the motors' rotation respectively, depend upon the magnitude of control voltages applied to the control windings of the amplidynes from the azimuth and elevation tracking unit.

These voltages depend upon the phase shift between the reference voltage and the error voltage applied to the input of the azimuth and elevation tracking unit.

During manual control, automatic circular or sector scanning the input of the azimuth and elevation tracking unit is fed with two independent error voltages (azimuth and elevation) of 50 c.p.s. frequency and one reference voltage of the same frequency.

During automatic target tracking the input of the unit is fed with one error voltage of 24 c.p.s. frequency containing azimuth and elevation

.../components,

components, and two reference voltages (azimuth and elevation) of the same frequency, which differ by 90° in phase.

One mode of operation is changed over to another by means of a function switch located on the panel of the antenna control unit.

During the antenna manual control the azimuth and elevation error voltage circuits are identical (Fig. 143).

Each of two error voltages is produced by a transmitting selsyn located in the antenna control unit and by a selsyn-transformer located in the antenna pedestal.

The rotors of the transmitting selsyns are retarded during manual control, while the stators are coupled through a mechanical linkage with the azimuth and elevation handwheels. The rotor of the azimuth selsyn-transformer is coupled through a 1:1 gear ratio with the shaft which rotates the antenna in azimuth while that of the elevation selsyn-transformer through a 1:4 gear ratio with the shaft rotating the antenna in elevation.

The rotor winding of the transmitting selsyn is supplied with 110 V, 50 c.p.s. The alternating magnetic field of the rotor induces in three stator windings alternating E.M.F. which feed the three stator windings of the selsyn-transformer.

The currents flowing in the selsyn-transformer stator windings set up a common alternating magnetic flux. If the axis of the rotor winding is perpendicular to the stator magnetic flux direction, then the voltage across the rotor winding is zero.

When the stator of the transmitting selsyn is turned by the handwheel the magnetic flux of the selsyn-transformer stator turns likewise and an alternating E.M.F. of 50 c.p.s. is induced in the winding of the selsyn-transformer rotor. This E.M.F. is used as an error voltage.

The magnitude of the A.C. voltage depends upon the angle of turn of

.../the transmitting selsyn,

the transmitting selsyn, while the phase is reversed by 180° with the change in the direction of the handwheel rotation.

The error voltage is applied to the input of the azimuth and elevation tracking unit. This unit is also supplied with a reference voltage at a frequency of 50 c.p.s. applied from the reference voltage transformer, located in the antenna control unit.

In the azimuth and elevation tracking unit the error voltage is converted with the help of the reference voltage into constant control voltage, applied then to the appropriate amplidyne. The magnitude and polarity of the voltage at the amplidyne output depend upon the magnitude and phase of the error voltage, i.e. upon the magnitude of the angle and direction of the rotation of the transmitting selsyn stator.

The amplidyne output voltage causes the appropriate drive motor to turn the antenna and the rotor of the selsyn-transformer so that the axis of the selsyn-transformer rotor winding is set at right angles to the stator magnetic flux, i.e. so that the error voltage is reduced to zero. In this instance the output voltage of the amplidyne falls to zero and the drive motor comes to a stop.

<u>During automatic circular scanning</u> the operation of the control system is similar to its operation during manual control except that the stator of the azimuth transmitting selsyn is rotated not manually, but by a circular scan motor located in the antenna control unit. The same motor can drive the elevation transmitting selsyn stator through a cam gear for automatic elevation sector scanning. The initial position of the antenna in elevation during scanning is set with the help of an elevation handwheel. Elevation scanning can be turned on or off by means of a mechanical switch located in the antenna control unit.

<u>During automatic sector scanning</u> the operation of the control system is identical to its operation during manual control or automatic circular

.../meaning,

scanning, except that the stators of the azimuth and elevation transmitting selsyns are turned in the assigned sector by the motor through special eccentrics.

Both during circular and sector scanning the automatic antenna swinging in elevation may be switched off.

During automatic target tracking in angular co-ordinates the error signal in the station is obtained by the use of the equisignal zone method (See Chapter I, Section 3).

In this case the error signal is produced as a result of continuous rotation of the antenna radiation pattern at a speed of 1440 r.p.m. (24 r.p.s).

The axis of the radiation pattern is off the antenna geometrical axis by 0-23. The latter during automatic target tracking will practically coincide with the direction of the equisignal zone or with the so-called antenna electrical axis.

If the direction of the target and the antenna electrical (geometrical) axis do not coincide, the electromagnetic pulses returned from the target and coming to the receiver input will be amplitude-modulated at a frequency of 24 c.p.s. The percentage modulation of the pulses depends upon the angle between the antenna electrical axis and the target direction, while the echo pulse envelope is determined by the deviation of the target in direction from the antenna electrical axis, i.e. by the relationship, of the deviation of the target in azimuth and elevation from the electrical axis.

From the output of the receiver automatic tracking channel the echo pulses, amplitude-modulated at a frequency of 24 c.p.s., are furnished to the input of the automatic tracking unit (Fig. 144) in which the pulse envelope voltage is separated and amplified.

The output voltage of the automatic tracking unit, which is referred

.../to as the error

to as the error voltage, is applied to the input of the azimuth and elevation tracking unit. Furthermore, the unit is supplied with two reference voltages of 24 c.p.s. which are 90° out of phase with each other.

These voltages are produced by the reference voltage generator located in the antenna pedestal. The generator rotor shaft is coupled to that of the antenna head.

In the azimuth and elevation tracking unit the error voltage is converted with the help of the two reference voltages into the azimuth and elevation control voltages, which are then applied to the control windings of the appropriate amplidynes.

The output voltages from the amplidynes are fed to the azimuth and elevation drive motors, which turn the antenna in azimuth and elevation so that the antenna electrical axis coincides with the target direction.

In this case the target echo pulses are amplitude-balanced, and therefore the output error voltage of the automatic tracking unit falls to zero and the drive motors come to a stop.

At any deviation of the target from the antenna electrical axis the echo pulses become amplitude-modulated at a frequency of 24 c.p.s., an error voltage is produced at the output of the automatic tracking unit and the drive motors turn the antenna in azimuth and elevation until its electrical axis coincides with the target direction.

When the target is moving the error signal continuously changes and causes the drive motors to turn the antenna thereby matching its electrical axis with the target direction.

2. OBTAINING THE ERROR SIGNAL DURING AUTOMATIC TARGET TRACKING

If the target is located on the axis of the radiation pattern (Fig. 145, Point A), the energy reflected from the target will be at maximum (let us say 100 per cent).

When the target is off the axis of the radiation pattern (Point B) by 0-08, the power of the echo signal makes up 95 per cent of the maximum, when shifted by 0-23 (Point C) is 80 per cent, and by 0-42 (Point D) is 50 per cent of the maximum value.

Due to the fact that radiating components of the antenna head are electrically asymetric with respect to the axis of its rotation, the direction of maximum radiation, i.e. the axis of the radiation pattern, is off the antenna electrical axis by 0-23.

During automatic target tracking the antenna head (and, consequently, the electromagnetic beam) is rotated about the antenna electrical axis at a speed of 1440 r.p.m. by the three-phase induction motor which drives simultaneously the rotor of the reference voltage generator.

In this instance the direction of maximum radiation describes a cone in space (Fig. 146).

If the target is on the antenna electrical axis (Fig. 147, a) the echo signal voltage at the receiver output is constant and makes up 80 per cent of the maximum possible value irrespective of the position of the electromagnetic beam in space.

If the target is off the antenna electrical axis by 0-23 (Fig. 147, b), the echo signal voltage at the receiver output varies from 30 to 100 per cent.

The envelope of the amplitude-modulated echo pulses is changed approximately sinusoidally. Since the electromagnetic beam rotates at a speed of 1,440 r.p.m., the frequency of the echo pulse envelope is:

$$\varphi = \frac{1440}{60} = 24 \text{ c.p.s.}$$

This frequency is inherent to two other voltages produced by the reference voltage generator, one of which is referred to as the azimuth reference voltage, the other as the elevation reference voltage. These two voltages have since wave forms and are 90° out of phase with

.../each other.

each other.

The angular value by which the echo pulse envelope is shifted in phase with respect to the azimuth and elevation reference voltages is determined by the deviation of the target from the antenna electrical axis in azimuth and elevation.

Fig. 148 shows the alteration of the echo signal voltage during one revolution of the antenna head for the following three cases:

- The target is off the antenna electrical axis in azimuth only.
- The target is off the antenna electrical axis in elevation only.
- The target is off the antenna electrical axis by the same angles both in azimuth and elevation.

In the first instance the envelope of the echo pulses is in phase with the azimuth reference voltage and, consequently, differs in phase by 90° with respect to the elevation reference voltage ($\varphi_\beta = 0^\circ$; $\varphi_\varepsilon = 90^\circ$).

In the second instance the envelope is in phase with the elevation reference voltage and is 90° out of phase with respect to the azimuth reference voltage ($\varphi_\beta = 90^\circ$; $\varphi_\varepsilon = 0^\circ$).

In the third instance the envelope is shifted in phase by the same angles relative to both reference voltages ($\varphi_\beta = 45^\circ$; $\varphi_\varepsilon = 45^\circ$).

In general the envelope of the echo signals may be considered as a sum of two A.C. components which are 90° out of phase with each other, the components characterizing the deviation of the target from the antenna axis in azimuth and elevation respectively.

A change of the magnitude of the angle between the target direction and the antenna electrical axis causes a change in the echo pulse amplitude limits, i.e. the echo pulse percentage modulation.

When the target is off the antenna electrical axis by 0-23 (Fig. 149, a) the modulation factor of the echo pulses is:

$$m = \frac{100 - 30}{100 + 30} = 0.54$$

If the target is off the antenna axis by 0-11.5 (Fig. 149, b), the

amplitude of the echo pulses varies from 40 to 90 per cent of the maximum possible value. Therefore, the modulation factor is:

$$m = \frac{90 - 40}{90 + 40} = 0.38$$

Thus, the percentage modulation of the echo pulses characterises the angular displacement of the target from the antenna axis, while the envelope phase with respect to the reference voltages characterises the direction of the target displacement from the antenna axis.

The echo pulse envelope is separated after the echo pulses have been detected in the automatic tracking unit and is used as an error voltage during automatic target tracking.

3. BLOCK-DIAGRAM OF ANTENNA POSITIONING SYSTEM DURING AUTOMATIC TARGET TRACKING

A block-diagram of the antenna positioning system during automatic target tracking is shown in Fig. 144.

The echo signals, which are amplitude-modulated at a frequency of 24 c.p.s., are picked up by the antenna and passed to the receiving system. As a result negative amplitude-modulated voltage pulses of 24 c.p.s. are obtained at the output of the receiver automatic tracking channel.

The output voltage of the receiver automatic tracking channel amplifier is applied to the input of the automatic tracking unit, which is composed of three stages.

The first stage, i.e. an error voltage detector, serves to convert short echo pulses into a voltage of constant polarity which changes depending on the form of the echo pulse envelope.

The output voltage of the detector stage consists of D.C. component and A.C. component of 24 c.p.s. fundamental frequency. Moreover, this voltage contains a series of higher harmonic components, comparatively small in amplitude.

The detector output voltage is applied to the second unit stage,

i.e. to the resonance amplifier with automatic gain control. In this stage the detector voltage fundamental A.C. component of 24 c.p.s. is separated, amplified and is then furnished to the third stage - a balanced amplifier. The latter produces a voltage of 24 c.p.s. referred to during automatic tracking as an error voltage.

The error voltage is fed from the automatic tracking unit to the input of the azimuth and elevation tracking unit.

The automatic tracking unit is comprised of two channels: an azimuth and an elevation channel.

During automatic tracking the input of both channels is fed with one common error voltage from the automatic tacking unit and two separate reference voltages of 24 c.p.s. frequency that are 90° out of phase with each other, fed from the reference voltage generator.

The reference voltages are used to separate the elevation and azimuth components from the common error voltage.

The error signal is divided into the azimuth and elevation components in the commutator stages of the azimuth and elevation channels.

The reference voltages are impressed on the commutator stages after these voltages have been converted by the forming stages into square-waves voltages.

As a result of combined operation of the error voltage and two reference voltages azimuth and elevation control voltages are generated at the output of the commutator stage filters. The control voltages are D.C. voltages whose magnitude and polarity depend upon the amplitude of the error voltage and phase relationship between the reference voltages and the error voltage.

Each control voltage is impressed on the input of the D.C. amplifier which employs two valves based on a balance circuit.

The amplified control voltage is used to feed the amplidyne control

.../windings.

windings.

The amplidyne amplifies the output power of the D.C. amplifier to a magnitude required for feeding the armature winding of the drive motor located in the antenna pedestal.

The field windings of the drive motors are fed with 300 V from the drive motor field winding power pack.

The magnitude and polarity of the amplidyne output voltage depend upon those of the control voltage which is determined by the deviation (in azimuth or elevation) of the antenna electrical axis from the target direction.

The automatic tracking system funtions so that at any deviation of antenna electrical axis from the target direction control voltages appear which, after having been amplified in the D.C. amplifiers of the azimuth and elevation tracking unit and in the amplidynes, are applied to the drive motors. These turn the antenna until its electrical axis coincides with the target direction.

When the antenna electrical axis is brought in line with the target direction the error voltage and, consequently, the output voltage of the amplidynes become equal to zero. However, the system inertia may cause the antenna to pass the position of the exact target direction. This will result in an error voltage of opposite phase, the polarity of the control voltages will be reversed and the motors will start turning the antenna to the target direction. But in this case the antenna may also overshoot the position of the exact target direction, etc. As a result hunting will occur.

To avoid hunting, the control system is damped by means of negative feedback generated by the counter-electromotive force of the drive motors.

The drive motor counter-electromotive force is applied through the feedback amplifier of the azimuth and elevation tacking unit.

.../The output voltage

The output voltage of the feedback amplifier acts on the D.C. amplifier in such a manner that when the antenna electrical axis approaches the target direction the control voltage decreases and the antenna slows down to the exact target direction.

As a result the antenna overshoot decreases and after swinging two or three times the antenna stops and points to the exact target direction.

To eliminate the antenna hunting with resultant overload of the drive motors the torque of the motors is limited by negative feedback developed by the drive motor armature current.

The voltage from the resistors connected in series with the drive motor armature circuit is applied to the torque limiting stage. The output voltage of this stage is impressed on the D.C. amplifier stage. When the armature current exceeds the permissible value, the torque limiting stage will act on the D.C. amplifier to reduce the control voltage. This will result in a decrease of the amplidyne output voltage and in a reduction of the drive motor speed.

4. OBTAINING THE ERROR SIGNAL DURING ANTENNA MANUAL CONTROL

The error signal during manual control, automatic circular or sector scanning is produced by means of transmitting selsyns and selsyn-transformers.

The azimuth and elevation error signals are obtained in the same manner, therefore let us consider the way the error signal is obtained in azimuth.

The transmitting selsyn is located in the antenna control unit. The selsyn rotor is fed with 110 V, 50 c.p.s. The movable stator of the transmitting selsyn is coupled through mechanical transmission to the handwheel controlling the antenna rotation in azimuth. The handwheel is situated on the front panel of the same unit. Three stator windings

 .../of the transmitting

of the transmitting selsyn are connected with those of the azimuth selsyn-transformer located on the antenna pedestal base plate.

Fig. 150 shows the arrangement of the stators and rotors of the transmitting selsyn and selsyn-transformer in case of maximum voltage across the rotor winding of the selsyn-tranformer.

The axis of the transmitting selsyn stator winding w_1 is at right angles to that of the rotor winding and, therefore, no electromotive force will be induced in it with alternating current flowing through the rotor winding.

The axes of the transmitting selsyn stator windings w_2 and w_3 are not perpendicular to the rotor winding axis and, therefore, A.C. electromotive forces will be induced in them by the action of the rotor variable magnetic flux.

The stator windings of the transmitting selsyn are connected with those of the selsyn-transformer, therefore by the action of the electromotive forces induced in the windings of the transmitting selsyn stator, the stator windings of the selsyn-transformer will handle alternating currents I_2 and I_3. They build up two variable magnetic fluxes Φ_2 and Φ_3 in windings w_2 and w_3 of the selsyn-transformer stator.

The resultant magnetic flux of the selsyn-transformer stator is a geometrical sum of two variable fluxes of stator windings w_2 and w_3 located in space at an angle of 60°.

The axis of the selsyn-transformer rotor winding is parallel to the resultant flux, therefore maximum voltage will be induced in the rotor winding.

If the rotor of the selsyn-transformer is turned by 90° (Fig. 151) the resultant variable magnetic flux of the selsyn-transformer stator is found to be at right angles to the axis of the its rotor winding. In this instance the electromotive force induced in the rotor winding of the

.../selsyn-

selsyn-transformer will equal zero.

Let us consider what will happen if the transmitting selsyn stator (position shown in Fig. 151) is turned clockwise through a certain angle (Fig. 152). The electromotive force induced in the transmitting selsyn stator windings makes the stator windings of the selsyn-transformer take alternating currents I_1, I_2 and I_3.

The total magnetic flux of the transmitting selsyn stator windings equal to the geometrical sum of the magnetic fluxes of all three windings has at any time the same direction as the rotor flux.

As the currents flowing through the appropriate stator windings of the transmitting selsyn and selsyn-transformer are equal, the resultant magetic flux of the selsyn-transformer stator is located with respect to the axes of the stator windings in the same way as the magnetic flux of the transmitting selsyn rotor to the axes of the selsyn stator windings.

Thus, after the transmitting selsyn stator has been turned through angle φ the resultant magnetic flux of the selsyn-transformer stator will turn through the same angle due to a change of the amplitude of the currents flowing through its windings.

In the rotor winding of the selsyn-transformer the electromotive force will be induced whose magnitude is proportional to component Φ_1 of resultant magnetic flux Φ, directed in parallel with the axis of the selsyn-transformer rotor winding (Fig. 152).

When turning the transmitting selsyn stator counter-clockwise through angle relative to the initial position (Fig. 153) the resultant magnetic flux of the selsyn-transformer will also turn counter-clockwise through the same angle relative to the initial position presented in Fig. 151.

In the selsyn-transformer rotor the E.M.F. will be induced by component Φ_1 of the resultant magnetic flux of stator Φ, the component

.../being in

being in parallel with the axis of the rotor winding. The direction of flux (Fig. 153) is opposite to that of flux Φ_1 (Fig. 152) obtained when turning the transmitting selsyn stator clockwise, therefore the voltage phase in the rotor of the selsyn-transformer in the latter case will differ by 180° from the voltage phase in the rotor winding in the former case.

When turning the transmitting selsyn stator clockwise through an angle from 0 to 90° relative to the initial position (shown in Fig. 151), the E.M.F. induced in the rotor winding of the selsyn-transformer will vary in value from 0 to 45 - 50V and again to 0 when turning it through 180°.

While turning the transmitting selsyn stator counter-clockwise relative to the given initial position, the E.M.F. in the rotor winding of the selsyn-transformer will vary within the same limits, but its phase will differ by 180°.

The arrangement of the stators and rotors of the transmitting selsyn and the selsyn-transformer shown in Fig. 151 when there is no E.M.F. in the selsyn-transformer rotor winding is called a static position.

Consequently, when the transmitting selsyn stator is turned through some angle from the static position an alternating E.M.F. will be induced in the selsyn-transformer rotor winding, whose magnitude and phase depend upon the magnitude of the angle and direction of the transmitting selsyn turn.

This is accompanied by a voltage appearing across the terminals of the selsyn-transformer rotor winding. This voltage is caused by the turn of the transmitting selsyn and is called the error voltage during manual control. In the initial position this voltage equals zero.

A block diagram of the antenna positioning system during manual control is presented in Fig. 154.

To rotate the antenna in azimuth it is necessary to turn the azimuth handwheel of the antenna control unit kinematically coupled with the stator

.../of the azimuth

of the azimuth transmitting selsyn. As a result the magnetic flux of the selsyn-transformer stator turns and an alternating E.M.F. is induced in the rotor winding. The E.M.F. develops an error voltage of 50 c.p.s. which is applied to the input of the commutator stage of the azimuth and elevation tracking unit.

The plates of the commutator stage valves are fed with a reference voltage of the same frequency as the error voltage (50 c.p.s.) squared in the forming stage.

The azimuth commutator stage produces D.C. control output the magnitude and polarity of which depend upon the magnitude and phase of the azimuth error voltage.

The successive elements of the antenna positioning system operate in the same way as during automatic tracking.

As the drive motor turns the antenna in azimuth, the rotor of the azimuth selsyn-transformer turns too.

When the stator of the transmitting selsyn is turned through an angle smaller than 180°, an error voltage is taken off the selsyn-transformer rotor, whose phase amounts to such a value at which the drive motor turns the antenna pedestal and the rotor of the selsyn-transformer as to reduce the error signal to zero. After two or three oscillations the antenna stops in a new position.

The antenna manual control in elevation is carried out similarly.

5. AUTOMATIC TRACKING UNIT

The automatic tracking unit (Fig. 155 and 156) serves to separate the error voltage of 24 c.p.s. from the video signals coming from the output of the receiver automatic tracking channel.

The automatic tracking unit consists of three stages (Fig. 157): an error voltage detector, a resonance amplifier and a balanced amplifier.

.../Moreover,

Moreover, the unit incorporates a rectifier to feed the automatic tracking unit, the azimuth and elevation tracking unit and the coarse antenna position selsyn.

The unit is mounted on three separate chassis. As viewed from the top (Fig. 156) the chassis located closer to the front panel carries receiving selsyns M6-1 and M6-2. The middle chassis carries the error signal detector, resonance and balanced amplifiers. The rear chassis mounts the rectifier feeding the automatic tracking as well as the azimuth and elevation tracking units.

A key diagram of the automatic tracking unit is presented in Fig.158 (See Album).

Error Signal Detector

The error signal detector (Fig. 159) serves to convert video pulses coming from the receiver automatic tracking channel into a continuously operating voltage whose magnitude changes similarly to the amplitudes of the receiver video pulses. The detector employs double diode 6H6S (V6-2). The valve cathode is fed with negative voltage pulses from the receiver automatic tracking channel through resistor R6-5.

During operation of the negative pulses capacitor C6-4 charges through resistor R6-5 and the valve. In the pulse intervals capacitor C6-4 slowly discharges through resistor R6-6.

The detector plate voltage changes following the alterations of the amplitudes of the video signals (applied to the detector input) and is an A.C. voltage with 24 c.p.s. fundamental frequency, containing the D.C. component.

The waveforms of the detector output and input voltages are shown in Fig. 160.

On account of the time constant of the charging circuit of capacitor C6-4 (Fig. 159) the A.C. component of the voltage lags in phase

.../by a certain

by a certain angle φ relative to the input pulse envelope. This phase shift is compensated for by an appropriate reversal of the reference voltage phase which is effected by turning the stator of the reference voltage generator.

From potentiometer R6-6 part of the negative relative to earth voltage acting across capacitor C6-4 is applied to the control grid of valve V6-3 (Fig. 158) of the resonance amplifier. The slotted shaft of potentiometer R6-6 is brought out to the front panel of the unit and is marked AGC.

Resonance Amplifier

The resonance amplifier is used to separate and amplify the A.C. component (of 24 c.p.s.) of the error voltage detector output and to reduce errors in determining angular co-ordinates caused by chance ripples of the echo signal amplitudes not dependent upon the rotation of the antenna radiation pattern in space.

The ripple of the echo pulses is caused by continuous variation of the size of the aircraft effective reflecting surface.

To reduce the effect of the echo pulse ripples on the target tracking accuracy the resonance amplifier uses valve V6-3, type 6K3, with variable transconductance (Fig. 161) due to which the gain is controlled automatically.

Voltage to the valve control grid is applied from potentiometer R6-6 (Fig. 158). The valve cathode is earthed through contacts of relay R6-2. The screen grid is fed with a voltage of +105 V from stabilovolt V6-5, type, 5G35.

The D.C. component of the error voltage detector output taken off potentiometer R6-6 is negative bias on the grid of valve V6-3.

By shifting the slider of potentiometer R6-6 the operating point on the characteristic of valve V6-3 is selected so that while picking up powerful echo signals the valve plate current that is measured by milliameter

.../Pp6-1

Pp6-1 located on the front panel of the unit PLATE CURRENT will equal 6 - 7 mA.

During pick up of weaker signals the D.C. component of the detector output voltage decreases, which results in a decrease of a negative bias voltage on the grid of valve V6-3, i.e. in the operating point being shifted to the right, to the section of the characteristic with higher transconductance. As a result the gain of the A.C. component of the error signal detector output increases.

During pick up of more powerful signals the D.C. component of the detector output voltage increases which results in the operating point being shifted to the left to the section of the characteristic with lower transconductance. As a result the gain of the A.C. component of the error signal detector output decreases.

Such an automatic gain control circuit smoothes quick oscillations of the error signal D.C. component which result from the ripple of the echo signals.

Automatic gain control (AGC) being employed, the A.C. component of the plate current of valve V6-3 in definite limits is independent of an average intensity of the echo signals. The given A.C. component is determined only by relative percentage of amplitude modulation of these signals, which depends only upon the angular deviation of the antenna axis from the target direction.

The plate circuit of valve V6-3 includes transformer Tr6-2. The A.C. component of the valve plate current creates (in the transformer) a variable magnetic flux, which induces an alternating electromotive force in the secondary winding.

The transformer secondary winding together with capacitors C6-8, C6-9 and resistor R6-7 constitutes a resonant circuit tuned to a frequency of 24 c.p.s. The secondary winding separates a sine-wave A.C.

.../voltage

voltage of 24 c.p.s. without the D.C. component with strongly reduced higher harmonics. This voltage corresponds in amplitude and phase to the fundamental harmonic of the error voltage detector output.

Resistor R6-7 serves to widen the circuit pass band. The centre tap of the transformer secondary winding is earthed. As a result two negative voltages equal in frequency and amplitude but 180° out of phase with each other, are acting across the two ends of the secondary winding. These voltages are applied to the grids of the balanced amplifier valve V6-4.

Balanced Amplifier

The balanced amplifier is designed for push-pull amplification of the error signal. It employs valve V6-4 (6N6S).

Voltages to the grids of the two amplifier triodes are taken from dual potentiometers R6-8 and R6-9. To check these voltages the front panel is provided with monitoring jacks G6-2 and G6-3 marked COUPLING TRANSFORMER. The shaft common for the sliders of dual potentiometers R6-8 and R6-9 is brought out to the front panel of the unit and is marked AMPLIFICATION.

Resistors R6-10 and R6-11 placed in the grid circuits of the balanced amplifier valve serve for clipping the grid current developed at large voltage amplitudes across the secondary winding of transformer Tr6-2.

The cathode of the two triodes of valve V6-4 are inter-connected and are earthed through rheostat R6-12 across which a voltage drop is developed due to the common plate current. The voltage drop serves as an automatic bias voltage. The value of this voltage is set by varying the resistance value of rheostat R6-12 whose slider shaft is brought out to the front panel of the unit and is marked 3 V (3B). To check this voltage jack G6-4 (3 V) is provided.

D.C. voltage to the triode plates of valve V6-4 is applied through common decoupling resistors R6-20 and R6-21, connected in parallel through

load resistors R6-13 and R6-15 and through balanced potentiometer R6-14, whose slotted shaft is brought out to the front panel of the unit and is marked BALANCE. Potentiometer R6-14 compensates for asymmetry of both halves of the double triode. Through isolating capacitors C6-6, C6-7 two error voltages are fed in phase opposition to the contacts of relay P10-1 located in the aximuth and elevation tracking unit.

Resistors R6-16 and R6-17 are grid leaks of the commutator stage valves of the azimuth and elevation tracking unit during automatic tracking. The connection point of these resistors is fed with a positive voltage of +75 V from a voltage divider formed by resistors R6-1, R6-2 and supplied with +300 V.

The voltage of +75 V is used as a D.C. bias voltage on the grids of the commutator valves in the azimuth and elevation tracking unit. To check this voltage jack G6-1 (75 V) is provided.

The error voltage may be checked across jacks G6-6 and G6-7 located on the front panel of the automatic tracking unit and marked COMMUTATOR INPUT.

Rectifier

The automatic tracking unit incorporates a rectifier based on a full-wave circuit employing kenotron V6-1, type 5C3S. A voltage of 110 V, 427 c.p.s. is applied through contacts 15 and 16 of knife-type connector Zw6-1, fuses B6-1, B6-2 and switch W6-1, located on the front panel of the unit, to the primary winding of power transformer Tr6-1. From the transformer secondary winding a voltage of 6.3 V is applied to the filament circuits of the valves in the automatic tracking and azimuth and elevation tracking units. The rectified voltage ripples are smoothed out by a filter consisting of choke D16-1 and capacitor C6-1.

A voltage of +300 V is applied to the plates of valves V6-3, V6-4 and stabilovolt V6-5 through damping resistors R6-18 and R6-19. From

.../the voltage

the voltage divider (resistors R6-1 and R6-2) the D.C. voltage of +75 V is fed to the centre taps of transformers Tr10-1 and Tr10-51 located in the azimuth and elevation tracking unit.

A voltage of +105 V is applied to the screen grid of valve V6-3 from stabilovolt V6-5, type SG3S.

A plate voltage of +300 V is fed to the azimuth and elevation tracking unit through switch W12-2 INTERLOCKING placed in the antenna control unit. Capacitor C6-2 is connected in parallel with the switch contacts, which prevents them from burning when opening the circuit.

Error Signal Cut-Off Relay

The error signal cut-off relay (P6-2) is used during automatic target tracking when the direction to the target being tracked is crossed by another target flying in close proximity to the first one.

In this case the input of the automatic tracking unit is fed with pulses reflected from both targets. This may lead to a false error signal and consequently missing the target. To avoid this it is necessary to press button W4-5 ERROR SIGNAL, OFF located on the front panel of the range mechanism unit.

When the button is pressed the relay winding is fed with voltage and the relay operates and grids of valve V6-4 become earthed through the relay contacts. As a result the error voltage at the output of the automatic tracking unit becomes zero and the antenna due to inertia force goes on moving in the target direction for two or three seconds. During this time the interfering target moves off to a distance at which the pulses reflected from it do not affect the very narrow gate. When the button is released the relay winding is de-energized, its contacts open, the error signal is applied to the grids of valve V6-4 and the antenna continues tracking the preselected target automatically.

The front panel of the unit is provided with jack G6-9 (DETECTOR) used when taking off gain-frequency characteristics of the system (this

jack is not provided in stations of the first production model).

Antenna Position Indicators

The automatic tracking unit incorporates receiving selsyns M6-1 and M6-2, type SS-404, which serve to indicate the antenna position.

The selsyn shafts carry scales, while pointers are marked on the fixed scale framings arranged on the front panel of the unit.

The azimuth scale is calibrated into 60 divisions; the elevation scale is calibrated from -2-00 to +15-00. The division valve of both scales is 0-50.

The scales are illuminated by lamps Z6-7 and Z6-8 fed by transformer Tr6-3.

The selsyns operate on 110 V, 50 c.p.s.

6. AZIMUTH AND ELEVATION TRACKING UNIT

The azimuth and elevation tracking unit (Figs. 162 and 163) serves to convert error voltages into control voltages.

The unit consists of two identical channels: an azimuth channel and an elevation channel mounted on two separate chassis. As viewed from the front panel the elements of the azimuth channel are located in the front section of the unit, while those of the elevation channel in the rear one. The azimuth channel controls are located on the front panel, to the right, and the elevation channel controls to the left.

All the elevation channel components bear the same numbers as the azimuth channel components plus fifty. For instance, the forming stage valve of the azimuth channel is indicated V10-3, and that of the elevation channel, V10-53.

Two D.C. milliameters located on the front panel of the unit serve to check the plate currents of the D.C. amplifier valves. By means of selector switch W10-1 ELEVATION AZIMUTH these instruments are connected to

/the D.C.

the D.C. amplifier circuit of the azimuth or elecation channel. With the selector switch in the middle position both instruments are disconnected.

A key diagram of the azimuth and elevation tracking unit is presented in Fig. 164 (See Album).

Each channel of the unit is composed of a forming stage, a commutator stage, a D.C. amplifier, a drive motor torque limiting stage, an antenna anti-hunt circuit and a feedback clipping stage.

Channels of the unit operate similarly, so we will consider the operation of the azimuth channel only.

Forming Stage

The forming stage is used for squaring the reference sine-wave voltage. The circuit of the forming and commutator stages is presented in Fig. 165. The azimuth channel forming stage employs valve V10-3, type 6N8S.

During manual control or circular and sector scanning the winding of relay P10-2 is de-energized and the voltages, equal in magnitude but opposite in phase are applied through the normally closed contacts of the relay to the grids of the forming stage valve from the secondary winding of transformer Tr12-3 situated in the antenna control unit. The centre tap of the secondary winding of transformer Tr12-3 is earthed. The voltage across the winding ends equals 200 V. The transformer primary winding is fed with 110 V, 50 c.p.s.

During automatic target tracking the winding of relay P10-2 is fed with 110 V, 50 c.p.s. - the relay contacts change its position and close the circuits supplying the grids of valve V10-3 with two voltages equal in magnitude but opposite in phase, that are taken off the secondary winding of transformer Tr13-1 located on the control panel.

The primary winding of transformer Tr13-1 is fed from a stator winding of the reference voltage generator.

.../The centre tap

The centre tap of the transformer winding is earthed. The value of the voltage across the secondary winding ends is 200 V, 24 c.p.s.

Thus, in any mode of operation two grids of valve V10-3 are fed with antiphase sine-wave voltages, having large amplitudes. During the half-cycle, when grid C_1 of valve V10-3 is fed with great negative voltage, triode A is cut off. Grid C_2 of triode B during this half-cycle is fed with great positive voltage, but due to grid currents all positive voltage is damped across resistor R10-31 (1 megohm). During the entire positive cycle the grid potential relative to the cathode is approximately zero.

The plates of the triodes of valve V10-3 are fed with +300 V through its load resistors R10-27, R10-28, R10-29 and R10-30. These resistors are plate load resistors common both for valve V10-3 and the commutator stage valves.

During those half-cycles of the reference voltage when one of the triodes of valve V10-3 is cut off its plate voltage rises to +150 V relative to earth (the rest of the voltage is dropped across the plate load resistors since they handle plate currents of the commutator valves).

At the same time the second triode of valve V10-3 is on and as a result of the plate current flowing through the plate load resistors its place voltage descreases to about +90 V relative to earth.

Thus, two-square-wave voltages are developed on the plates of the forming stage valve V10-3. The cycle of this voltage equals that of the reference voltage. These two voltages are applied to the plates of the forming stage valves V10-1 and V10-2.

Commutator Stage

As described above, the amplitude and phase of the error voltage (relative to the reference voltages) depend upon the magnitude and direction of the antenna electrical axis deviation from the target direction.

This error voltage contains two components, one of which is caused

.../by the

by the target deviation in elevation only.

If the antenna electrical axis deviates by some angle from the target direction the error voltage may be expressed as follows:

$$U = k\ \delta \sin\left(2\pi Ft + \Psi_\beta\right) =$$

$$k\ \delta\ \sin\Psi_\beta \cos 2\pi\ Ft + k\ \delta\ \cos\Psi_\beta \sin 2\pi\ Ft,$$

where F - antenna head rotation frequency equal to 24 c.p.s.;

Ψ_β - phase shift angle between error voltage and azimuth reference voltage;

- proportionality coefficient.

Fig. 6 shows that

$$\Delta_\varepsilon = \delta \sin\Psi_\beta ; \quad \Delta_\beta = \delta \cos\Psi_\beta ;$$

then $U = U_\varepsilon \cos 2\pi Ft + U_\beta \sin 2\pi Ft$

where $U_\varepsilon = k\ \Delta_\varepsilon$, $U_\beta = k\ \Delta_\beta$.

Consequently, the sine-wave error voltage may be presented as a sum of two sine-wave voltages that are 90° out of phase with each other, one voltage having an amplitude proportional to the angular deviation of the antenna electrical axis from the target in a horizontal direction (U_β), the other to the deviation of the antenna electrical axis from the target in a vertical direction (U_β).

The error signal is separated into two components in the commutator stage with the help of reference voltages.

The azimuth commutator stage produces D.C. output voltage (azimuth control voltage) of which the magnitude is proportionate to the amplitude of the error voltage azimuth component, i.e. to the magnitude of angular deviation Δ_β.

The polarity of the azimuth control voltage depends upon whether the azimuth component of the error signal is in or out of phase with the azimuth reference voltage, which in turn depends upon the sign of angular deviation Δ_β.

The elevation commutator stage produces output elevation control

voltage which is determined similarly by the magnitude and sign of angular deviation Δ_{ε}.

The azimuth commutator stage employs valve V10-1 and V10-2 (Fig. 165), type 6N8S.

During automatic target tracking the winding of relay P10-1 is fed with 110 V, 50 c.p.s. through selector switch W12-1 MODE OF OPERATION, located in the antenna control unit. In this case the relay contacts close the circuits supplying the grids of the commutator valves of both stages with the common error voltage coming from the output of the automatic tracking unit.

During manual control and circular or sector scanning the winding of relay P10-1 is de-energized. In this case error voltage from the rotor winding of azimuth selsyn transformer M32-4 is impressed on the commutator valve grids of azimuth channel through step-up transformer Tr10-1 and contacts of relay P10-1. Error voltage is also applied from the rotor winding of elevation selsyn-transformer M32-54 to the grids of the elevation channel commutator valves through contacts of relay P10-2, step-up transformer Tr10-51 (Fig. 164) and contacts of relay P10-1.

As seen from Fig. 165 the plates of the first and third triodes of the commutator stage (A_1 and A_3) are connected with plate A_2 of forming valve V10-3. The plates of the second and fourth triodes (A_2 and A_4) are coupled with plate A_1 of valve V10-3.

Let us take a look at the commutator stage operation in the absence of error voltage.

Each triode of the commutator valves has such characteristics that with the plate voltage of +150 V (relative to earth) and grid voltage of +75 V (relative to earth) the triode conducts and handles the current which develops a voltage drop of +76 V across the valve cathode load resistor (R10-5 or R10-6 equal to 20 kilohms).

Consequently, in this case the triode operates at plate voltage

Ua = 74 V and grid voltage Ug = -1 V.

If the triode plate is under +90 V relative to earth and the grid potential is approximately equal to the cathode potential the triode is practically cut off in consequence of too low magnitude of the plate voltage (Ua = 14 V).

From this it follows that during the first half-cycle of the reference voltage, when the voltage on plate A_2 of valve V10-3 is +150 V and on plate A_1 of the same valve is +90 V, triodes 1 and 3 of the commutator stage are on, while triodes 2 and 4 are cut off.

During the next half-cycle of the reference voltage when the voltage on plate A_2 of valve V10-3 is +90 V and on plate A_1 of the same valve is +150 V, triodes 2 and 4 are on, whereas triodes 1 and 3 are cut off.

Consequently, during any half-cycles of the reference voltage (in the absence of the error voltage) one triode of valve V10-1 and one triode of valve V10-2 are conducting and plate currents of these triode equal voltage drops (76 V) across cathode resistors R10-5 and R10-6 (Fig. 166).

Let us consider the operation of the commutator stage with the error voltage applied in phase with the reference voltage (Fig. 167, a).

As seen from Fig. 167, a, during the first half-cycle of the reference voltage triodes 1 and 3 are conducting since the voltage on its plates is +150 V relative to earth.

The plate currents of triodes 1 and 3 create voltage drops of approximately 70 - 80 V across the cathode load resistors.

At this time the plates of triodes 2 and 4 are under +90 V relative to earth, consequently the plate voltages of these triodes are no more than 10 to 20 V and therefore the plate current in triodes 2 and 4 are practically equal to zero.

The values of the plate currents in triodes 1 and 3 and, consequently,

.../the cathode

the cathode voltages of these valves are determined during the first half-cycle of the reference voltage by the values of the voltages on grids S_1 and S_3.

Grid S_1 is at this time under a positive half-cycle of the error voltage, whereas grid S_3 under a negative half-cycle. As a result the cathode voltage of valve V10-1 is increased, while that of valve V10-2 decreased as compared with their magnitudes in the absence of error signal.

During the next half-cycle of the reference voltage the plate voltages of all the four triodes change, which results in triodes 2 and 4 being triggered and triodes 1 and 3 cut off. At this time the magnitudes of the valve plate currents and consequently voltages on the valve cathodes are determined by the voltages on grids S_2 and S_4. Since grid S_2 is fed with a positive half-cycle of the error signal and grid S_4 with a negative half-cycle the voltage on the cathode of valve V10-1 will be increased, as is the case during the first half-cycle of the reference voltage, whereas that on the cathode of valve V10-2 decreased as compared with their magnitudes in the absence of the error voltage.

Thus, the average magnitude or D.C. component of the voltage on the cathode of valve V10-1 is found to be higher than +76 V, while that on the cathode of valve V10-2 lower than +76 V.

The potential difference between the cathodes of valves V10-1 and V10-2 is called control voltage.

If the error signal phase is reversed by 180° the conditions of valves V10-1 and V10-2 are reversed too and the voltage on the cathode of valve V10-1 is found to be lower than +76 V, while that on the cathode of valve V10-2 higher than +76 V.

Consequently, a reversal of the error voltage phase by 180° causes a change of the control voltage polarity.

The control voltage is applied through the filter to the grids of valves V10-4 and V10-5 of the D.C. amplifier. At the filter output, i.e.

between grids of valves V10-4 and V10-5 the mean potential difference of magnitudes between the cathodes of valves V10-1 and V10-2 is obtained.

The operation of the commutator stage with phase shift of 90° (or 270°) between the error and the reference voltages is illustrated by a chart presented in Fig. 167, b.

In accordance with the changes in the plate voltages during the first half-cycle of the reference voltage, triodes 1 and 3 remain on and during the second one, triodes 2 and 4.

At the beginning of the first half-cycle the cathode voltage of valve V10-1, according to the chart of voltages on grid S_1, is higher than 76 V while at the end of it lower than +76 V by the same value.

At the beginning of the first half-cycle the cathode voltage of valve V10-2, according to the chart of voltages on grid S_3, is found lower than +76 V, whereas at the end of it higher than +76 V.

During the second half-cycle of the reference voltage the grid voltages of triodes 2 and 4 change in the same way as those of triodes 1 and 3 during the first half-cycle. Therefore, the charts of voltages on the cathodes of valves V10-1 and V10-2 during the second half-cycle will be the same as during the first half-cycle.

It is seen from Fig. 167, b, that the chart of voltages on the cathodes of valves V10-1 and V10-2 are symmetrical relative to the initial level of +76 V and the mean value of the valve cathode potentials remains the same as it was in the absence of the error signal.

Consequently, when the error voltage is 90° (or 270°) out of phase with the reference voltage the commutator stage control voltage equals zero.

From this it follows that if the azimuth commutator is fed with an error voltage caused by the target deviation in azimuth (azimuth error signal) it is found to be in phase (or out of phase) with the azimuth

.../reference

reference voltage and an azimuth control voltage appears at the commutator output.

The same error voltage applied to the input of the elevation commutator does not create a control voltage at its output, since the elevation reference voltage is shifted in phase by 90° with respect to the azimuth reference voltage and, consequently, the phase shift between the azimuth error voltage and the reference voltage in the elevation commutator equals 90°.

We have already considered the process of conversion of the error voltage into the control voltage when the phase shift between the error and reference voltages is 0° or 90°. These cases correspond to the target deviation from the antenna electrical axis in azimuth or elevation only.

During simultaneous deviation of the target from the antenna electrical axis both in azimuth and elevation the phase shift between the error and the reference voltages has some intermediate values.

The voltage wave forms for a 30° and 60° phase shift are presented in Fig. 168, a and b.

When the phase shifts from 0° to 30° the cathode potential of valve V10-1 changes depending upon the potential of grids S_2 and S_4.

With the phase equal to 30° the plate voltage changes instantaneously and valve V10-1 comes to be controlled by grids S_1 and S_3. When the phase is reversed from 30° to 210° cathode potential changes depending upon the potential of grid S_1, With the phase equal to 210° the plate voltage changes again depending upon the potential of grids S_2 and S_4 until the cycle ends.

The mean value of the cathode potential of valve V10-1 exceeds the value of the cathode potential in the absence of the error voltage by appropriately smaller value than in the case of the phase coincidence.

The form of voltage changes when phase is shifted by 60° differs from

.../the one

the one considered above in that the voltage jumps occur at 60° and 240°. The control voltage, i.e. the potential difference between the cathodes of valves V10-1 and V10-2 is smaller in this case than at the 30° phase shift.

Thus, when analysing the operation of the commutator stages the error voltage should be considered as a sum of its two sine components, of which one, i.e. an azimuth component, is in phase with the azimuth reference voltage and the other, i.e. an elevation component, is in phase with the elevation reference voltage.

From this it follows that the azimuth commutator produces a control voltage depending only upon the azimuth component of the error signal, whereas the elevation commutator a control voltage depending only upon the elevation component of the error signal.

During manual control the grids of both forming valves are fed with the common reference voltage. The grids of the azimuth commutator valves are fed with the error voltage from the rotor winding of the azimuth selsyn-transformer, while the grids of the elevation commutator valves, from the rotor winding of the elevation selsyn-transformer.

The forming and commutator stages operate similarly both during manual control and automatic target tracking.

The voltage produced in the rotor winding of the selsyn-transformer can reverse its phase only by 180°. Therefore, the error voltage in the commutator stage may be either in phase or out of phase with the reference voltage. Consequently, the magnitude of the control voltage during manual control depends only upon the amplitude of the error voltage, while during automatic target tracking the magnitude of the control voltage depends upon the amplitude of the error voltage and the phase shift between the error and the reference voltages.

The control voltage from resistors R10-5 and R10-6 is applied to the control grids of the D.C. amplifier valves through the filter (Fig. 169).

The filter is designed for smoothing out the ripples of the cathode

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voltages of valves V10-1 and V10-2. The filter produces a mean value of control voltage. It passes slow fluctuations of the control voltage which are caused by changes in deflection of the antenna axis from the target direction. More rapid fluctuations of the control voltage caused by occasional ripples of the echo signal intensity are weakened by the filter.

D.C. Amplifier

The amplifier is based on a balanced circuit employing valves V10-4 and V10-5, type 5P3S (Fig. 169). The amplifier valve control grids are fed with the output voltage of the commutator through a filter formed by capacitors C10-1, C10-2, chokes Dl10-1, Dl10-2 and resistors R10-20, R10-21.

The D.C. amplifier feeds the amplidyne control windings. In the absence of the control voltage the plate current of valve V10-4 equals that of valve V10-5. In this case the magnetic flux of the control winding connected into the plate circuit of valve V10-4, is equal in magnitude and opposite in direction to that of the control winding connected into the plate circuit of valve V10-5.

Magnetic fluxes of the control windings are mutually compensated and the total control magnetic flux equals zero. In this case the voltage at the amplidyne output also equals zero.

Milliammeters Pp10-1 and Pp10-2 situated on the front panel of the unit serve to measure the plate currents of the D.C. amplifier valves of the azimuth or elevation channel.

The plate currents are determined by measuring a voltage drop across resistors R10-25, R10-26 for the azimuth channel and across R10-75, R10-76 (Fig. 164) for the elevation channel.

Potentiometers R10-8 and R10-58 (whose shafts are brought out to the front panel of the unit and designated FIELD CURRENT) serve for adjusting the plate currents of the D.C. amplifier valves. In the absence of the control voltage the plate current of each amplifier valve should be equal to 25 mA.

During manual control or automatic target tracking a control voltage

The control voltage causes the plate current of one of the valves to increase, the magnetic flux of the control winding connected into the plate circuit of this valve to rise; the plate current of the second valve to decrease, thus bringing about a decrease of the magnetic flux of the control winding connected into its plate circuit. A resultant magnetic flux appears and a voltage is developed at the amplidyne output. The reversal of the error voltage phase causes the reversal of the control voltage polarity.

Connected in parallel with the azimuth amplidyne windings are resistors R10-40 and R10-41 used to select the required amplification of the azimuth channel. The resistance value is selected (within 3 to 8.2 kilohms) when tuning the antenna control unit in gain-frequency characteristics.

The D.C. amplifier is acted on by two separate feedback voltages: a feedback voltage to limit the drive motor torque (acts on the control grids of the D.C. amplifier valves) and a feedback voltage to eliminate the antenna hunting (acts on the screen grids of the D.C. amplifier valves).

Torque Limiting Circuit

During sharp turns of the manual control handwheel or hunting of the antenna in automatic target tracking the error voltage at the input of the azimuth and elevation tracking unit sharply rises. This causes an increase of the control voltage, the amplidyne output voltage and the current flowing through the drive motor armature.

To cancel out this undersirable effect which may result in overloads and failure of the motor and reduction gear use is made of a torque limiting circuit (Fig. 170).

The circuit operation depends upon the fact that the rise of the motor drive armature current above the rated value triggers the torque limiting valve and reduces the magnetic excitation flux of the amplidynes.

The cathode voltage of valve V10-9 (6N9S) equal to +34 V is set by

.../potentiometer

potentiometer R10-33, whose slider shaft is brought out to the front panel of the unit and designated TORQUE LIMITING. The triode grids are connected to resistors R32-1 and R32-2 placed in the circuit of the drive motor armature. The mid-point of the resistors is under a +30 V potential.

Thus, in the absence of current in the motor armature and resistors R32-1 and R32-2 connected in series with it, the grids of valve V10-9 are also under the same potential (+30 V). The plates of valve V10-9 are coupled to the control grids of the D.C. amplifier the potential of which is approximately equal to +76 V.

With such voltages on the electrodes both triodes of the torque limiting valve are cut off. When applying a great control voltage to the D.C. amplifier valve grids the motor armature will handle a heavy current.

Suppose the direction of current through the armature will cause the potential on the upper end of resistor R32-2 to become positive relative to the mid-point. In this case the voltage on the grid of triode II of valve V10-9 will rise and when it has attained a definite value, the valve will conduct, decreasing the control voltage on the grid of D.C. amplifier valve V10-5.

The decrease of the grid current will bring about a reduction of the valve plate current and a decrease of the amplidyne field current. The field current decrease causes a decrease of the motor armature current. Since valve V10-9 has a large amplification factor the limitation is performed quickly and the current flowing through the armature does not exceed the permissible value.

A reversal of the control voltage polarity will cause the current to flow in opposite direction through the armature and triode I of valve V10-9 will function as a limiter. At normal operation the motor armature handles a current smaller than permissible and both triodes of valve V10-9 are cut off.

The magnitude of the maximum torque is set by potentiometer R10-33

(marked TORQUE LIMITING). When raising the cathode potential of valve V10-9 with the help of potentiometer R10-33 the permissible torque increases due to an increase of the permissible current flow through the motor armature. When reducing the cathode potential of valve V10-9 the permissible torque decreases.

Antihunt Circuit

Owing to the system inertia the antenna cannct stop at once and overshoots the position at which the error signal equals zero. This results in appearance of the error signal of opposite phase, the antenna starts moving in the cpposite direction and overshoots the above position again, etc.

Thus, in the system may occur periodic hunting of the antenna about the required position to eliminate which an antihunt circuit is provided (Fig. 171).

This circuit uses a feedback voltage applied from the drive motor armature circuit to the D.C. amplifier screen grids. It may be considered that the antihunt circuit produces a feedback voltage, whose polarity and magnitude of instantaneous values characterise the direction and magnitude of instantaneous values of the antenna hunting speed near the error signal zero position. The circuit responds only to the speed variations, and produces no voltage if the antenna turns at a constant speed. Consequently, the circuit exerts no influence on the drive system.

The feedback voltage is applied to the screen grids of the D.C. amplifier valves (V10-4 and V10-5) in polarity which ensures the antenna hunting retardation.

While the error signal voltage causes the antenna to move towards the error signal zero position, the feedback voltage reduces the difference of the amplifier valve plate currents and, consequently, the amplidyne output voltage. This results in the antenna approaching the error signal zero

.../position

position at a lower speed.

When the antenna, after passing the error voltage zero position, turns further, moving away from this position, the feedback voltage, preserving the former polarity, increases the difference between the amplifier plate currents which is created by the error voltage that shifted its phase by 180°. Consequently, at this time the feedback voltage adds to the action of the error signal thereby ensuring more rapid retardation and stopping of the antenna.

Thus, the feedback voltage, both when the antenna approaches the error signal zero position and moves away from it, causes retardation of the antenna hunting. As a result the antenna after making two or three oscillations stops in a position corresponding to the error signal zero position.

To obtain feedback voltage use is made of electromotive force induced in the drive motor armature. The magnitude and polarity of the electromotive force for any D.C. machine with separate excitation, are determined by the speed and direction of the motor armature rotation, i.e. by the speed and direction of rotation of the antenna.

In order to make the feedback voltage be determined only by the electromotive force induced in the drive motor armature and be independent of the amplidyne output voltage use is made of a bridge connection whose four arms are: (1) resistor R10-34, (2) resistor R10-22, (3) the drive motor armature resistance and resistor R32-1, (4) the amplidyne commutating winding resistance and resistor R32-2.

The amplidyne output voltage is applied to one bridge diagonal while the feedback voltage is taken off the other. If the bridge is balanced, the voltage taken off the second diagonal does not depend upon the amplidyne voltage, but is proportionate only to the electromotive force induced in the drive motor armature.

However, the bridge is not balanced precisely and the feedback

circuit is fed with a voltage proportionate to the motor current, i.e. to acceleration. This makes the tracking system more stable at high frequencies.

The voltage taken off the second bridge diagonal is applied to a feedback filter formed by capacitors C10-4, C10-5, C10-6, choke D110-3, resistor R10-23 and potentiometer R10-24.

The filter passes only A.C. components of the feedback voltage with frequencies higher than 1 c.p.s. Therefore, during uniform rotation of the antenna or during slow variations of its speed determined by the change of angular co-ordinates of the target being tracked the feedback voltage taken off potentiometer R10-24 equals zero. In addition the feedback filter changes the amplitude and phase of the A.C. feedback voltage, thereby improving conditions for reducting the antenna hunting when tracking a moving target.

The A.C. feedback voltage produced at the filter output during the antenna hunting is applied from potentiometer R10-24 to the control grids of triodes 1 and 3 of the feedback amplifier valves V10-6 and V10-7, type 6N8S. Voltage to the plates of the feedback amplifier valves and screen grids of the D.C. amplifier valves are applied through common load resistors R10-10, R10-35, R10-11, R10-36.

As both halves of the feedback amplifier are coupled through cathode resistors R10-19 and R10-37 voltages of opposite sign are developed on the plates of valves V10-6 and V10-7 and, consequently, on the screen grids of valves V10-4 and V10-5.

In the presence of the feedback voltage the plate current of one D.C. amplifier valve increases while that of the other decreases or vice versa.

Potentiometer R10-12 permits variation (in certain limits) of the constant grid potentials of triodes 2 and 4 of valves V10-6 and V10-7 whose magnitude must be approximately equal to +30 V. This makes it possible

.../to initially

to initially balance the plate currents of the D.C. amplifier valves.

The shaft of potentiometer R10-12 is brought out to the front panel and is marked BALANCE.

The feedback magnitude is adjusted by means of potentiometer R10-24 whose shaft fitted with a knob is brought out to the front panel and is marked FEEDBACK.

Feedback Limiting Circuit

During sharp variations of the error signal amplitude which may occur when changing over from manual control to automatic tracking, the feedback voltage may exceed the error signal, which will result in the target being missed. To diminish the feedback effect the unit is provided with a feedback limiting circuit employing valve V10-8, type 6H8S.

In the absence of the feedback voltage the grid potential of valves V20-6 and V10-7 is usually equal to +30 V. Valve V10-8 is so connected that the plate potential of diode II and cathode potential of diode I is +30 V respectively. The plate potential of diode I of valve V10-8 equals +22 V, and cathode potential of diode II of the same valve is +38 V.

If the feedback voltage is positive and exceeds 8 V the potential on the grids of the first and third triodes of the feedback amplifiers will be in excess of +38 V. The plate potential of diaode II will be greater than the cathode potential; the diode will conduct and the surplus feedback voltage will be damped across resistor R10-18.

If the feedback voltage is negative and exceeds 8 V, the potential on the grids of the first and third triodes of the feedback amplifier and on the cathode of diode I will be lower than 22 V; the diode will conduct and the surplus feedback voltage will be damped across resistor R10-18.

The voltages at which the diode is conducting can be adjusted by dual potentiometer R10-14, R10-15, whose shaft is brought out to the front panel of the unit and is marked FEEDBACK LIMITING.

7. ANTENNA CONTROL UNIT

The antenna control unit (Figs. 172 and 173) serves to control the antenna rotation both during circular or sector scanning and manual control.

The unit incorporates the following components: azimuth transmitting selsyn M12-1 (Fig. 174), elevation transmitting selsyn M12-51, circular scan motor M12-2, azimuth follow-up motor M12-3, elevation follow-up motor M12-52, transformers Tr12-1 and Tr12-51 reducing the voltage from 10 to 2.5 V, transformers Tr12-2 and Tr12-52 reducing the voltage from 110 to 21 V, reference voltage transformer Tr12-3, electromagnetic brakes E12-1 and E12-51, capacitors C12-1, C12-52 and C12-51.

The front panel of the unit (Fig. 172) carries: on the right - azimuth control handwheel 5, on the left - elevation control handwheel 2, knob 1 of function switch (W12-1) MODE OF OPERATION, knob 6 of switch SCAN SELECTION, switch 7 INTERLOCKING (W12-2), handle 4 of selector switch ELEVATION COVERAGE and selector switch 3 A.A. DIRECTOR MONITORING - OPERATION (W12-3).

A kinematic diagram of the antenna control unit is presented in Fig. 175 (See Album).

Rotation is imparted from the azimuth handwheel to the stator of the azimuth transmitting selsyn M12-1 through a gear transmission consisting of two pairs of spur gears (27:108 and 48:96) and a cone differential. The total gear ration from the azimuth handwheel to the stator of transmitting selsyn M12-1 is

$$i = \frac{11}{216}$$

The construction of the transmitting selsyns makes possible independent rotation of their stators and rotors.

Rotation is imparted from the elevation handwheel to the stator of elevation transmitting selsyn M12-51 through a gear transmission consisting of three pairs of spur gears (28:70, 36:108 and 90:60) and a cone

differential. The total gear ratio from the elevation handwheel to the stator of transmitting selsyn M12-51 is

$$i = \frac{1}{10}$$

During manual control the rotors of transmitting selsyns M12-1 and M12-51 are retarded by de-energized electromagnetic brakes E12-1 and E12-51.

Rotation cannot be imparted to circular scan motor M12-2 since the motor worm reduction gear with ratio $i = \frac{1}{41}$ is of the self braking type. Therefore the differential imparts rotation from the handwheel to the transmitting selsyn stator only.

The handwheel shafts carry adjustable electromagnetic brakes E12-1 and E12-51 which prevent rotation of the handwheels when the unit operates in other modes.

To make the handwheel rotation more smooth use is made of inertia flywheels coupled to the control handwheels through gears $z = 120$ and $z = 40$.

During circular scanning the stators of transmitting selsyns M12-1 and M12-51 are driven by circular scan motor M12-2. The circular scan motor is a two-phase A.C. induction motor, type 2 ASM-400. The motor is supplied with 110 V, 50 c.p.s. through contacts of selector switch W12-1 (MODE OF OPERATION) 90° phase shift is created by capacitor C12-52 (Fig.174).

The stator of azimuth transmitting selsyn M12-1 is driven by motor M12-2 through the worm reduction gear, two pairs of spur gears and the cone differential. The total gear ratio from the circular scan motor to the stator of transmitting selsyn M12-1 is

$$i = \frac{3}{328}$$

During circular scanning the antenna rotates in azimuth at a speed of 10 to 13 r.p.m. and simultaneously swinging in elevation.

The stator of the elevation transmitting selsyn M12-51 is driven by motor M12-2 through a worm reduction gear with gear ratio $i = \frac{1}{41}$,

.../pairs of

pairs of spur gears $z = 50$, $z = 100$, $z = 25$, $z = 100$, $z = 31$, $z = 93$, a cam gear, pair of spur gears $z = 80$ and $z = 60$; a cone differential with gear ratio $i = \frac{1}{2}$, pair of spur gears $z = 90$ and $z = 60$.

The cam gear consisting of a cam, a lever, a sector and a spur gear causes the stator of the elevation transmitting selsyn to oscillate. The elevation cam profile is designed so that for eight ninths of its revolution the antenna is lifted by an angle of about 2-00 and for one ninth of the cam revolution is lowered down to the initial position.

The elevation scan can be turned on or off by means of selector switch ELEVATION COVERAGE.

During sector scanning the stators of the transmitting selsyns are driven similarly as during circular scanning, i.e. by circular scan motor M12-2.

The total gear ratio from the circular scan motor to the stator of transmitting selsyn M12-1 is

$$i = \frac{159}{4592}$$

The cam gear of the azimuth sector drive consists of a cam, a lever, a sector and a spur gear. The cam profile is designed so that during the complete revolution of the cam the azimuth transmitting selsyn stator oscillates within a sector of 4-00 to 9-00 at a speed of 30 complete oscillations per minute.

The sector scan is switched on by placing handle SCAN SELECTION to position SECTOR. In this case the worm reduction gear shaft is disengaged from the differential and the azimuth sector drive circuit is energized. Simultaneously the elevation cam rotation sector is switched over and the antenna oscillates in elevation within about 2-00, the antenna being lifted for four complete oscillation in azimuth and lowered down for one complete (fifth) oscillation.

During automatic target tracking voltage from the rotors of selsyn-

transformers M32-4 and M32-54 (Fig. 176, see Album), located in the antenna pedestal, is applied through the contacts of relays P10-1, P10-2, located in the azimuth and elevation tracking unit, to follow-up motors M12-3 and M12-52, connected to the rotors of the transmitting selsyns through spur gears. In this case the electromagnetic brakes release the rotors of the transmitting selsyns.

The antenna and the selsyn-transformer rotors coupled to it are driven automatically in accordance with the target movement.

If the rotors of the transmitting selsyns remain in the same position they have obtained when changing over from manual control to automatic tracking, and the antenna during automatic tracking is turned through a certain angle, then, when coming back to manual control again, a strong error signal will be developed in the selsyn-transformers, which will cause a sharp turning of the antenna.

To eliminate sharp jerks of the antenna when changing over from one mode of operation to another follow-up motors M12-3 and M12-52 set the rotors of transmitting selsyns M12-1 and M12-51 (during automatic tracking) to such a position at which the error signal of the selsyn-transformer approaches zero.

To rotate the follow-up motors (type ASM-50) two magnetic fluxes are required shifted in space and in phase by 90° with respect to each other. One flux is created by a winding fed with 20 V from step-down transformer Tr12-2 (or Tr12-52) connected into 110 V, 50 c.p.s. circuit. The other flux is created by a winding fed from the selsyn-transformer through matching transformer Tr12-1 (Tr12-51). A phase shift by 90° is obtained by means of capacitors C12-1 and C12-51 placed respectively into the supply circuits of the azimuth and elevation follow-up motors.

The follow-up motor will rotate until the transmitting selsyn rotor is set in a position at which the voltage across the selsyn-transformer

rotor approaches zero.

During manual control the rotors of the transmitting selsyns are held in place by electromagnetic brakes E12-1 and E12-51 whose coils are de-energized in this case.

When setting the MODE OF OPERATION SELECTION switch in position AUTOMATIC, relays P10-1 and P10-2 located in the azimuth and elevation tracking unit operate, and their contacts make the path for the error voltage to the input of the commutator stages of both channels of the azimuth and elevation tracking unit from the automatic tracking unit; voltages from the rotors of selsyn-transformers M32-4 and M32-54 are applied to follow-up motors M12-3 and M12-52 of the antenna control unit; reference voltages of 24 c.p.s. are fed by the reference voltage generator to the azimuth forming stage from transformer Tr13-1 and to the elevation forming stage from transformer Tr13-2. Both transformers are located on the control panel. Then electromagnetic brakes E12-1 and E12-51 operate, attracting their armatures and releasing the gearing from the follow-up motors and coupling them to the rotor of the transmitting selsyns. Furthermore, field current is applied and armature circuits of tachogenerators M32-6 and M32-56 located in the antenna pedestal are energized; relay P1-1 switches on the receiver A.G.C.

When selector switch W12-1 is set in position MANUAL or SCAN relays P10-1 and P10-2 are de-energized. Their contacts conduct error signals from the selsyn-transformers to the commutator stages of the azimuth and elevation tracking unit. Reference voltages are applied through the other contacts of these relays to the forming valves of both channels from transformer Tr12-3; the coils of the electromagnetic brakes are de-energized, the tachogenerators and the receiver A.G.C. circuit are switched off.

The antenna control unit incorporates switch A.A. DIRECTOR MONITORING -

.../OPERATION

OPERATION (W12-3) breaking the supply circuit of relays P10-1 and P10-2 when it is set in the A.A. DIRECTOR MONITORING position. In this case field voltage is applied to tachogenerator M32-6 and M32-56 irrespective of the position of selector switch W12-1. The tachogenerators feed voltages proportional to the antenna rotation to monitor the A.A. fire director operation.

When the station operates in combat conditions selector switch W12-3 should always be kept in the OPERATION position.

8. ANTENNA PEDESTAL

The antenna pedestal (Fig. 177) is designed to accommodate the azimuth and elevation rotors as well as the selsyn drives and azimuth and elevation tachogenerators.

The antenna pedestal (Fig. 178) is comprised of the following components: an azimuth motor drive, an azimuth selsyn drive, an elevation motor drive, an elevation selsyn drive, a current collector, a parabolic reflector.

The pedestal mounts part of the antenna-feeder system with the reference voltage generator and the antenna rotating head.

The base plate for the antenna pedestal is a round cast-iron plate in the middle of which is the bearing of the pedestal main vertical shaft. The second bearing of the shaft is mounted in the head of the tripod resting against three wedge-shaped shoes.

Fitted rigidly on the shaft are the main azimuth gear z = 118 and double gear z = 320 and z = 200 of the azimuth selsyn drive. The gears are engaged with the help of a stop-gear. The same vertical shaft mounts a current collector (located above the main azimuth gear) consisting of 35 slip-rings separated by insulation rings. Contact is provided by brushes fitted over the slip-rings. The brushes are located on two panels mounted on the silumin current-collector body secured in the tripod

The plate of the elevation selsyn drive is connected to the frame of the elevation drive motor by a bridge to which a bracket is attached carrying the reference voltage generator, the parabolic reflector and the sight. The pedestal base plate is provided with level indicators to level the antenna pedestal.

The bracket attached to the elevation selsyn drive frame mounts a reference level intended for checking and setting the level indicators located on the pedestal base plate.

The antenna is oriented by means of an optical sight mounted on the reflector bracket.

A kinematic diagram of the antenna pedestal is presented in Fig. 179 (See Album).

Azimuth Motor Drive

The main azimuth gear comes in mesh with output gear z = 21 of the azimuth motor drive (Fig. 180) which is a reduction gear (z = 12, z = 60, z = 124, z = 96) enclosed in a cast-iron case. The reduction gear is driven by motor M32-3 (Fig. 179), type M1-12f, 0.2 kW, located on the upper cover of the reduction gear case. Mounted here is azimuth tachogenerator M32-6 coupled with the motor shaft by bevel gear $i = \frac{9}{20}$ (z = 27, z = 60).

The pedestal main shaft is rotated in azimuth by drive motor M32-3 through a floating clutch, a reduction gear and pair of output gears z = 21, z = 118 coupling the pedestal shaft with the reduction gear.

The total gear ratio of the azimuth motor drive mechanism is i = 224.8.

Azimuth Selsyn Drive

Placed round the double gear of the azimuth selsyn drive are coarse and fine transmitting selsyns M32-1 and M32-2, the plan-position indicator system transmitting selsyn M32-5 and azimuth selsyn-transformer M32-4 (Fig. 181). The selsyns are installed in vertical casings mounted on the

.../base

base plate and are secured in them by means of eccentric rings, with the help of which gear clearance is taken up. The azimuth selsyns are rotated by the double gear ($z = 320/200$) coupled through the stop to the main azimuth gear of the pedestal.

The stop-gear consists of a leverage and a pinion engaged with the double gear. While in operation the stop-gear is clamped with the help of a handle located on the main azimuth gear. The pinion is rigidly coupled with the main azimuth gear and imparts rotation to the double gear.

When the stop-gear is tripped the pinion is rotated about its axis and enables the double gear to rotate freely with the main azimuth gear motionless.

The double gear is connected with a setting pinion ($z = 16$) by means of which the rotors of the azimuth selsyns can be set when orienting the station. Fitted on the same shaft with the setting pinion is bevel gear $z = 50$. The second bevel gear $z = 20$ coming in mesh with the first one is pressed off by a spring during the radar operation. When orienting the station, trip the stop gear, press the orientation handle and by turning it set the selsyns in the required position.

The rotors of coarse transmitting selsyn M32-1, P.P.I. selsyn M32-5 and selsyn-transformer M32-4 are connected to the pedestal shaft through gear ratio $i = \frac{1}{1}$. The rotor of fine transmitting selsyn M32-2 is coupled to the pedestal shaft through gear ratio $i = \frac{20}{1}$.

To illuminate the scale of the fine transmitting selsyn use is made of lamp Z32-1, type MM-15, and switch W32-1; the lamp circuit is provided with damping resistor R32-5.

Elevation Motor Drive

Fitted rigidly on the upper end of the main shaft is a head carrying a horizontal shaft, whose one end mounts an elevation motor drive (Fig.182) while the other, an elevation selsyn drive (See Fig. 183).

The elevation motor drive is a worm reduction gear ($k = 5$, $z = 72$, $z = 17$, $z = 85$), enclosed in a cast silumin case that is rotated by drive motor M32-53, type M1-12f mounted on the drive case. When the motor operates output gear $z = 15$ of the reduction gear, while rotating, moves along stationary toothed sector $z = 200$ rigidly fitted on the horizontal shaft and thereby imparting elevation rotation to the reduction gear case and the parabolic reflector rigidly coupled with it.

A special compartment of the reduction gear case accommodates limit switches (microswitches) W32-51 and W32-52 which are included into the antenna elevation retardation circuit. They operate when the flat cams located on the toothed sector are pressed.

To protect the elevation drive mechanisms from damage (when the electric retardation circuit is faulty) the elevation motor drive is provided with a special device for disengagement from the sector. For this purpose gear $z = 15$ is unlocked on the output shaft of the elevation motor drive and can freely rotate on it. It comes in mesh with the shaft through a clutch with end cams which is spline-fitted on the shaft and is pressed to gear $z = 15$ by spring. With the reflector in extreme positions the clutch slips along the gear thus permitting it to freely turn on the shaft until the motor comes to a stop.

The total gear ratio of the elevation drive mechanism is 800. The reflector can turn in elevation within -0-50 to +14-50.

Tachogenerator M32-56 is coupled to drive motor M32-53 through gearing $i = \frac{5}{6}$ ($z = 60$, $z = 95$, $z = 50$). Relay P32-5, type R5-13-1, damping resistors R32-8, R32-9, range resistor R32-7 and potentiometer R32-11 connected into the tachogenerator circuits are located on the antenna pedestal base plate.

Elevation Selsyn Drive

The elevation selsyn drive (Fig. 183) is a vertical steel plate which mounts coarse and fine elevation transmitting selsyns M32-51 and M32-52

and elevation selsyn-transformer M32-54. The selsyns engage toothed sector [illegible] = 320 and gear z = 150 by means of gears fixed on the selsyn shafts.

When the parabolic reflector rotates in elevation the selsyn gears roll along the toothed sector, thus imparting rotation to the selsyns.

The selsyns are mounted in the plate on eccentric rings performing the same function as in azimuth selsyns. The plate with selsyns is closed on both sides with cast covers. The latter are provided with openings closed with bolted caps. The caps may be removed, if necessary.

The rotor of the coarse transmitting selsyn is coupled to the shaft rotating in elevation through gearing i = 1 (z = 150, z = 150). The rotor of the fine transmitting selsyn is coupled to the shaft rotating in elevation through gearing i = 20 (z = 320, z = 16). The elevation selsyn-transmitter rotor is coupled to the shaft rotating in elevation through gearing i = 4 (z = 320, z = 80).

The selsyn drive plate carries resistor R32-3 and connector Zw32-1 to energize the sight illumination lamp or an orientation lamp (Zw32-2).

The main shaft and the horizontal shaft are tubes which accommodate the coaxial feeder and wires to feed the elements of the elevation motor and selsyn drives.

Located at the lower end of the main shaft is an azimuth rotating joint of the feeder, while at the end of the horizontal shaft an elevation rotating joint.

Current Collector

The current collector (Fig. 184) consists of thirty-five silver slip-rings, 1 separated by pertinax rings 3. The rings are fitted on a hollow shaft which accommodates the central feeder and hook-up wires running to the current collector. Current is collected from each slip-ring by means of graphite brushes 2 fitted over the rings. The brushes are soldered to leaf bronze springs which are attached to two textylite terminal blocks P13-7 located in symmetry with the shaft. The terminal

blocks are fixed to the current collector body 5 by three screws. The current collector body is a silumin casting secured rigidly to the base and tripod.

Parabolic Reflector

The parabolic reflector is a rigid aluminium perforated structure. Reflector 2 (Fig. 177) is attached to its silumin case by means of a frame, inserts and steel rings. The case is installed on a bridge rigidly coupled to the case of elevation motor drive 6 and elevation selsyn drive 5. The centre of gravity of the parts rotating in elevation is somewhat displaced relative to the horizontal shaft, therefore to balance the rotating parts a counterpoise is secured on the elevation selsyn drive case.

To install the antenna head in the reflector focus the reflector body may be moved along the radiation axis by widening the holes for bolts securing the body to the bridge.

Antenna Pedestal Electric Circuit

The elements located in the antenna pedestal are electrically connected to other elements of the station through terminal blocks P132-1, P132-2, P132-3, P132-4, P132-5 (Fig. 185).

The elements located in the elevation section of the pedestal are electrically connected to other elements through current collector P132-7.

The wires from the current collector slip-rings to the elevation motor drive run to block P132-8 and then in four cables are branched off to separate elements. The wires from the current collector slip-rings to the elevation selsyn drive run in one bundle to block P132-9 and from the block they are branched off to the selsyns and damping resistor R32-53.

The antenna may turn in elevation within -0-50 to +14-50. To slow down the antenna speed when it approaches the extreme positions (-0-50 and +14-50) special limiters are used. This prevents excessive mechanical strains on the stops.

When the antenna approaches the lower stop limit switch W32-51 (Fig. 186) operates and a circuit composed of the winding of relay P32-1 and selenium rectifier D13-1 is connected in parallel with the windings of elevation amplidyne M34-51, whose control winding resistance is much greater than the circuit resistance.

When the pedestal moves towards the stop the potential on point A of the amplidyne control winding is lower than that on point B, therefore current will flow through the winding of relay P32-1 and rectifier D13-1. In this case selenium rectifier D32-1 slightly by-passes the relay winding, since its reverse resistance is too large as compared with the winding resistance of relay P32-1.

Relay P32-1 picks up and closes the supply circuit of relay P32-3 which operates to short-circuit terminals D2 and K2 of the amplidyne. This is accompanied by disconnection of the compensating winding from the amplidyne output and a sharp increase of the amplidyne armature interference acting counter to the magnetic flux of the control windings. The amplidyne sharply reduces the output voltage. In this case the motor counter-electromotive force exceeds the amplidyne output voltage and reverse current starts flowing through the drive motor circuit and the compensating winding connected into circuit.

The motor begins to work during dynamic braking and rapidly changes the number of revolutions. Besides, the reverse current, through the compensating winding, creates a magnetic flux which is opposite to the control flux. As a result the voltage across the amplidyne is practically zero despite incomplete balancing of current across control windings of the amplidyne which in this case is at no-load. The motor in the braking circuit is rapidly braked and the pedestal strikes with much weaker force against the elastic stops.

With the pedestal removed from the lower stop the potential of point B becomes lower than that of point A. Relay P32-1 starts handling

an appreciably smaller current than during the pedestal approach to the lower stop, since in this case large reverse resistance of selenium rectifier D13-1 is connected in series with the winding of relay P32-1. Selenium rectifier D32-1 with its direct low resistance shunts the winding of relay P32-1. The latter drops out and breaks the supply circuit of relay P32-3. The relay contacts open and break the motor braking circuit. The amplidyne begins producing voltage which acts on the motor and makes it move the pedestal away from the stop.

When the antenna approaches the upper stop limit switch W32-52 operates similarly and causes the circuit of relay P32-2 and selenium rectifiers D32-2 and D13-2 to function.

The pedestal base plate carries: relay P32-4, type RS-13-40; damping resistors R32-3, R32-4, range resistor R32-6; potentiometer R32-10, wire-wound resistors R32-51 and R32-52, resistor R32-54 reducing the elevation amplidyne short-circuit current during operation of the electric braking circuit, blade connector Zw32-1 carrying jack-in connector Zw32-2. Through connector Zw32-1 the antenna pedestal attaches a meter for measuring the station gain-frequency characteristic, connector Zw32-2 being removed.

Resistors R32-1 and R32-2 connected into the torque limiting and the feedback bridge circuits of the azimuth channel are located on the cover of the azimuth reduction gear.

Drive Motors

To rotate the antenna in azimuth and elevation motors, type M1-12f, (Fig. 187) are employed in the station.

The motor, type M1-12f, is a D.C. four-pole, separately excited machine. The field winding is fed with 300 volts D.C. from a separate rectifier and consumes a current of 75 mA.

The rated voltage across the motor armature is 110 V, the rated current is 2.46 A. With the given voltage across the motor armature and

300 volts across the field winding the motor develops a speed of 3000 r.p.m. and 0.2 kW power.

The direction of the motor rotation depends upon the polarity of voltage applied to the armature winding, while the rotation speed upon the voltage magnitude. The drive motor armature winding is fed with the amplidyne output voltage, therefore the antenna rotation is determined by the change of the amplidyne output voltage.

The motor is provided with a block with terminals Sz_1 and Sz_2 (the field winding terminals), W_1 and W_2 (the armature winding terminals). To suppress radio interference during switching operations a capacitive filter is provided.

Drive Motor Field Winding Supply Rectifier

The rectifier is designed as a separate unit (Fig. 188) which is located in the amplidyne cabinet.

The rectifier is based on a full-wave circuit using kenotron V66-1, type 5C3S (Fig. 189). A supply voltage of 110 V, 50 c.p.s. is applied to power transformer Tr66-1 with line contactor P31-1. The output voltage of the rectifier is +300 V.

Reference Voltage Generator Set

To rotate the antenna head and the reference voltage generator use is made of a three-phase induction motor. The motor and the generator are enclosed in a common housing.

The connections of the motor-generator set are presented in Fig. 190.

The three-phase winding of the reference voltage generator motor is star-connected and is supplied with a voltage of 220 V, 50 c.p.s. The rated voltage across each phase of the generator is 33 V.

Fitted on the rotor shaft of the motor is a permanent magnet rotating in the generator stator at a speed of 1440 r.p.m. and inducing two E.M.Fs of 24 c.p.s. shifted in phase by 90° in the two generator stator windings.

These E.M.Fs create azimuth and elevation reference voltages across the stator winding terminals. The phase of the reference voltages depends upon the arrangement of the magnet and the generator stator.

The reference voltage generator stator is so constructed that it can be turned through a certain angle by means of an adjustable screw located on the generator side surface. By means of this screw the stator is set so that with the target deviating only in azimuth relative to the antenna electrical axis the error signal at the output of the automatic tracking unit is in phase with the azimuth reference voltage and 90° out of phase with the elevation reference voltage.

9. AMPLIDYNES

The station is provided with two amplidynes, type WEM-5, located in a cabinet (Fig. 191).

The amplidyne is a generator of a special type intended for power amplification.

The amplidyne (Fig. 192) consists of a special D.C. generator whose armature is rotated by a three-phase A.C. induction motor. The motor and generator are enclosed in a common housing.

The motor rating: 0.93 kW, 3 A, 2850 r.p.m.

The generator is provided with two control windings (U_1, U_2 and U_3, U_4). The D.C. output voltage of the generator with the difference of currents flowing through the control windings equal to 10 mA is 115 V (at no-load).

The generator is rated as follows: output power is 0.37 kW; output current is 4.35 A and voltage is 85 V. To control the amplidyne output power a low power in the control circuit is required.

The amplidyne control windings are connected to the plate circuits of the D.C. amplifier valves in the azimuth and elevation tracking unit.

The armature of the amplidyne generator is similar in construction

to that of a normal two-pole D.C. generator. The difference lies in the fact that two pairs of brushes shifted by 90° with respect to each other are arranged on the commutator. Two brushes of one pair (a-a in Fig. 193) are interconnected and form a shorted circuit of the machine armature. The other pair of brushes ($W_1 - W_2$) takes the machine load current.

The amplidyne stator is assembled from sheet steel punchings and is provided with two main shaped poles and two commutating poles. The stator carries commutating windings $E_1 - E_2$, compensating winding $K_1 - K_2$ connected in series with the load circuit, control windings U_1, U_2 and U_3, U_4 and a demagnetising winding placed on the poles of the control windings.

The control windings are so connected to the D.C. balanced amplifier that they carry currents in opposite directions. If these currents are equal in magnitude the resultant field flux is zero and the amplidyne is not excited.

If voltages applied to the D.C. amplifier cause the current in one control winding to increase and the current in the other control winding to decrease, relatively small magnetic flux Φ_1 is developed directed along the stator axis (Fig. 193).

When the armature is rotated, flux Φ_1 of the control windings induces electromotive force in the armature causing large current I_2 in the armature shorted circuit.

Current I_2 creates flux Φ_2 directed along the lateral axis. This flux is the main field flux. When the armature is rotated it remains stationary and induces (in the armature winding between working brushes $W_1 - W_2$) electromotive force E_3 acting in the amplidyne load circuit.

If this load is connected directly to brushes $W_1 - W_2$ current I_3, that appeared in the armature by the action of electromotive force E_3, will create armature interference flux Φ_a, opposite directed to flux Φ_1 along the longitudinal axis. Owing to this the resultant flux along the longitudinal axis will be reduced approximately to zero, which will cause

.../a decrease

a decrease of flux Φ_2 and consequently of electromotive force E_3.

To cancel out demagnetizing effect of the amplidyne load current, placed in series with the armature is compensating winding $K_1 - K_2$ building up flux Φ_K equal in magnitude but opposite in direction to armature interference flux Φ_a.

The compensating winding is designed so as to compensate for the armature interference along the longitudinal axis. To regulate the magnitude of the armature interference use is made of resistor R_b connected in parallel with the compensating winding. The compensation magnitude is set at the Manufacturing plant.

The commutating windings $E_1 - E_2$ serve to improve current commutation by brushes $W_1 - W_2$ of the amplidyne operating circuit.

The generator stator iron is magnetised by a magnetic flux created by difference currents of the D.C. amplifier and preserves part of magnetism (residual magnetism) after the control winding currents have been equalized. The residual magnetism flux causes appearance of residual voltage at the amplidyne output. This voltage considerably decreases the accuracy of automatic target tracking by reducing the system reaction to weak signals and introducing accidental errors.

To reduce the magnitude of residual voltage the amplidyne uses a demagnetising winding which is placed on the generator control poles and is fed with alternating current of 50 c.p.s.

The demagnetising winding is supplied from one of the amplidyne drive motor windings (Fig. 192).

The magnetic flux created by the demagnetising winding, changes its direction depending upon the circuit frequency (50 c.p.s.) and cancels part of the residual magnetism thereby reducing residual voltage.

.../Chapter 8

Chapter 8

DATA TRANSMISSION SYSTEM

1. GENERAL

The data transmission system is designed to transmit target data produced by the station to the anti-aircraft fire director or other equipments associated with the station (LSPPM, search-light). Besides, the system makes it possible to pick up target data from the early warning station and for the antenna to be remotely controlled from the PUAZO-6.

The main control panel of the station is supplied by selsyns with the following data characterising the antenna position:

- Coarse azimuth and elevation data to the antenna position indicators located in the automatic tracking unit.

- Fine azimuth and elevation data to the receiving selsyn unit located on the cabin wall near the main control panel.

The anti-aircraft fire director and the search-light are furnished with the following data determining the target present position:

- Target azimuth, coarse and fine readings ($\beta_{c.r.}$, $\beta_{f.r.}$).

- Target elevation, coarse and fine readings ($\varepsilon_{c.r.}$, $\varepsilon_{f.r.}$).

- Target slant range, coarse and fine readings ($\Delta_{c.r.}$, $\Delta_{f.r.}$).

Apart from this, when the SON-9 operates in conjunction with the PUAZO-6 it produces:

- A constant voltage proportionate to the azimuth rate (ω_β);

- A constant voltage proportionate to the elevation rate (ω_ε).

When picking up target data from the early warning station, the SON-9 is supplied with the following data:

- Target azimuth, coarse reading ($\beta_{c.r.}$).

.../- Target

- Target slant range, coarse reading ($\Delta_{c.r.}$).

The data transmission system incorporates the following units and components:

- Coarse antenna position indicators located in the automatic tracking unit.

- A receiving selsyn unit.

- Four transmitting selsyns, type DI-511, located in the antenna pedestal.

- Two transmitting selsyns, type DI-511, located in the range mechanism unit.

- Two tachogenerators, type GT-1, located in the antenna pedestal.

- The station external boards.

The data transmission system includes a system conveying coordinates to the equipments associated with the SON-9 station, a target indication system and a remote control system from the PUAZO-6.

2. DATA TRANSMISSION

The block diagram of the data transmission system is presented in Fig.194. Solid lines with arrows on the diagram show electrical coupling between elements, while dashed lines, mechanical coupling.

The key diagram of the data transmission system is given in Fig.195.

The station antenna pedestal (See kinematic diagram in Fig.179) accommodates four transmitting selsyns, type DI-511, (Fig.196, a) and two tachogenerators, type GT-1 (Fig.197).

Coupled to the shaft rotating the antenna in azimuth (Fig.195) are:

- Coarse azimuth transmitting selsyn M32-1 (gearing 1:1).

- Fine azimuth transmitting selsyn M32-2 (gearing 1:20).

- Azimuth tachogenerator M32-6 (Fig.185).

Coupled to the shaft rotating the antenna in elevation (Fig.195) are:

- Coarse elevation transmitting selsyn M32-51 (gearing 1:1).

.../- Fine

- Fine elevation transmitting selsyn M32-52 (gearing 1:20).

- Elevation tachogenerator M32-56 (Fig.185).

The range mechanism unit incorporates coarse transmitting selsyn M4-4 (Fig.195) and fine slant range transmitting selsyn M4-3 kenematically coupled to the slant range shaft through gearings 20:1 and 1:1, respectively.

The azimuth, elevation and slant range data (coarse and fine) are conveyed from the transmitting selsyns to connectors Zw33-2 AA DIRECTOR and Zw33-3 SEARCHLIGHT, situated on the right-hand external board. Besides, each of them is supplied with 110 V, 50 c.p.s. to feed the stator windings of the receiving selsyns, located in the anti-aircraft fire director and the searchlight.

Inside the station the azimuth and elevation transmitting selsyns (coarse and fine) furnish the data to the antenna position indicators and the receiving selsyn unit. The indicators are used for showing coarse position of the radar antenna (coarse azimuth and elevation).

The receiving selsyns are electrically connected with the corresponding transmitting selsyns located in the antenna pedestal.

Used as antenna position indicators M6-1 and M6-2 are receiving selsyns, type SS-404, (Fig.196, b), situated in the front part of the automatic tracking unit.

The shaft of each selsyn mounts a disc with a scale. The azimuth scale is calibrated into 60 large divisions, the elevation scale is calibrated from -2-00 to +15-00. The division value of both scales is equal to 0-50.

The receiving selsyn unit (Fig.198) serves to indicate fine position of the antenna in azimuth and elevation.

The unit incorporates two receiving selsyns, type SS-404, (azimuth selsyn M44-1 and elevation selsyn M44-2). One revolution value of the fine azimuth and elevation scales is 3-00, the division value of these scales

is 0-01. The key diagram of the receiving selsyn unit is shown in Fig.199 (See Album).

The operating principle of the selsyn drive system is as follows. The selsyn consists of a stator with a single-phase winding placed in its slots and a rotor with a three-phase winding. The stator windings of the transmitting and receiving selsyns are arranged in parallel and are connected to 110 V, A.C. supply. The windings of both rotors are interconnected. When the selsyn rotors are similarly oriented relative to their stators, electromotive forces equal in magnitude but opposite in sign (phase) are induced in the rotor windings. Therefore the leads connecting the rotor windings do not carry current and the rotors are motionless.

If the rotors are oriented differently electromotive forces of various magnitudes are induced in the rotor windings, the difference between them being dependent upon the magnitude of the mismatch angle of the selsyns. Consequently, current appears in the rotor windings which produces torque on both rotors. The position of the transmitting selsyn rotor is fixed by the rotating mechanism, while the receiving selsyn rotor may rotate freely. The rotor of the receiving selsyn rotates until it obtains such a position at which equal electromotive forces are induced again in the rotor windings of both selsyns. This position of the receiving selsyn rotor corresponds to a new position of the transmitting selsyn rotor.

To obtain constant voltages proportionate to angular speeds of the target movement in azimuth ω_β and elevation ω_ε the azimuth and elevation motor drives of the antenna pedestal accommodate tachogenerators of the GT-1 type.

The tachogenerator is a D.C. generator whose voltage, (when field current value is constant) is proportionate to its armature speed. In various tachogenerators the relationship between output voltage and the armature speed is sometimes disturbed. Deviations are compensated for by

.../changing the

changing the tachogenerator field current, which is achieved by selection of range resistors at the Manufacturing plant placed in series with the tachogenerator field winding: R32-6 for the azimuth tachogenerator and R32-7 for the elevation tachogenerator (Fig.200).

The tachogenerators are protected from overloads at high angular speeds of the antenna pedestal by relays P32-4 and P32-5, type RS-13, located in the azimuth compartment of the pedestal.

The relay windings are connected to the amplidyne outputs. When the relay windings handle currents exceeding a definite value the relays trip off thereby inserting damping resistors R32-3, R32-4 and R32-8, R32-9, in the field circuit of the tachogenerators, which results in a decrease of field current and appropriate reduction of the tachogenerator output voltage.

The relay operating current is set in such a way that azimuth relay P32-4 operates when the output voltage of the azimuth tachogenerator reaches 200 to 220 V, whereas elevation relay P32-5 when the output voltage of the elevation tachogenerator reaches 160 to 220 V.

To set the operating current of azimuth relay P32-4 and elevation relay P32-5 variable resistors R32-10 and R32-11 are placed in series with their winding circuits.

During automatic scanning or manual control the tachogenerator circuits are opened by switch MODE OF OPERATION. Thus, voltage is taken off the tachogenerators only during automatic target tracking.

The tachogenerator field windings are fed from the PUAZO-6 through connector Zw33-5 AA DIRECTOR ANGULAR SPEED located on the left-hand external board of the station.

3. TARGET DATA RECEPTION

Target data are picked up from the early warning station with the help of the selsyn drive (Fig.195).

.../Coarse azimuth

Coarse azimuth and slant range data are furnished from the early warning station to the SON-9 through connector Zw33-4 TARGET INDICATOR located on the right-hand external board.

When the station is switched to pick up target data selector switch GUN-LAYING RADAR - EARLY WARNING STATION (RSA - RSWP)* in the receiving selsyn unit (Fig.198) should be set in position EARLY WARNING STATION (RSWP [MOST]). In this case the receiving selsyns are set to pick up the target data from the early warning station:

the fine azimuth receiving selsyn as a coarse azimuth receiver;

the fine elevation receiving selsyn as a coarse slant range receiver.

The data during this mode of operation are read on the inner scales of the receiving selsyns with respect to the pointers fixed on the plexiglass in front of the scale. One revolution of the azimuth scale corresponds to 60-00, while a division value to 0-50; one revolution of the range scale corresponds to 80 km., a division value to 500 m. The position of the pointers is set when the SON-9 selsyn drive is matched with the early warning station.

4. REMOTE CONTROL FROM PUAZO-6

When the radar station is tracking multiple targets within visibility range and when its operation is affected by interference (active or passive) the target present data (slant range, azimuth, elevation) may be determined by means of an optical range finder directly from the PUAZO-6.

The station design provides for automatic homing of the antenna pedestal on the target both in azimuth and elevation from the PUAZO-6. If conditions permit, the selected target is tracked by the radar station in range automatically or manually since the slant range is determined by the station more precisely than by the PUAZO-6. The slant range present data produced by the station are passed to the PUAZO-6.

* In stations of earlier design the switch is marked GROM-MOST.

The antenna is remotely controlled from the PUAZO-6 by means of transmitting selsyns and selsyn-transformers whose operating principle is described in Chapter 7. In this case coarse azimuth and elevation transmitting selsyns M32-1 and M32-51 placed in the antenna pedestal serve as transmitting selsyns whereas selsyns, type SS-405 (Fig.196, c), located in the PUAZO-6 and kinematically coupled with its range-finder serve as the selsyn-transformers.

The simplified diagram of the remote control system from the anti-aircraft fire director is shown in Fig.201.

During remote control by PUAZO-6 azimuth and elevation selsyn-transformers M32-4 and M32-54 of the antenna pedestal are disconnected from the azimuth and elevation tracking unit and connected through contacts of relays P10-1 and P10-2 to follow-up motors M12-3, M12-52 of the antenna control unit. The azimuth and elevation selsyn-transformers located in the PUAZO-6 are connected to the azimuth and elevation tracking unit.

The follow-up motors of the antenna control unit being fed with control voltage from the azimuth and elevation selsyn-transformers of the antenna pedestal turn the rotors of transmitting selsyns M12-1 and M12-51 to eliminate the antenna hunting when the radar station is switched over from remote control to control from the station control unit.

To cancel out continuous oscillations of the antenna in azimuth (due to large amplification in the antenna positioning system) when the station is remotely controlled from the PUAZO-6 the input of the azimuth and elevation tracking unit azimuth channel is shunted by resistor R13-1 located on the control panel together with selector switch W13-7 (AA DIRECTOR CONTROL - STATION).

5. EXTERNAL BOARDS OF STATION

The external boards (Fig.202) are located on the left-hand cabin wall (looking forward). Their connection diagram is presented in Fig.203.

SECRET

.../The right-hand

The right-hand external board carries:

- Connector Zw33-1 (POWER UNIT) to feed voltages of 220 V, 50 c.p.s. and 110 V, 427 c.p.s. to the station.

- Connector Zw33-2 (AA FIRE DIRECTOR) to feed the target present data (coarse and fine azimuth, elevation, slant range).

- Connector Zw33-3 (SEARCHLIGHT) to furnish the searchlight with the target present data (coarse and fine azimuth, elevation, slant range).

- Connector Zw33-4 (TARGET INDICATOR) to pick up azimuth and slant target data (coarse) from the warning station.

- Two pairs of telephone line terminals (L33-1 to L33-4).

- 6-V socket-contact G33-7 to feed a portable lamp.

- 6-V board lighting lamp (Z33-1).

- Board lighting lamp switch W33-1.

- Terminal EARTH (Z33-5).

The left-hand external board carries:

- Connector Zw33-5 (AA DIRECTOR ANGULAR SPEED) to pass voltages proportionate to angular speeds of the target movement from the tachogenerators to the PUAZO-6.

- Connector Zw33-6 (AA DIRECTOR REMOTE CONTROL) to connect selsyn-transformer of the PUAZO-6 to transmitting selsyns M32-1 and M32-51 of the station during remote AA director control.

- Four pairs of terminals to attach telephone lines (L33-6 to L33-13).

- 6-V board lighting lamp (Z33-2).

- Board lighting lamp switch W33-2.

- Terminal EARTH Z33-14.

6. TELEPHONE COMMUNICATION CIRCUIT

The radar station is provided with external telephone communication (Fig.204). The telephone line terminals are located on the external boards of the station. Inside the station are two telephone sockets to which are connected telephones, one having two lines in parallel and the other

Chapter 9

POWER SUPPLY SYSTEM

1. GENERAL

The power supply system serves for distributing electric energy obtained from the power unit to the systems and devices of the radar station.

The power supply system includes a control cabinet located on the right of the main control board, a control panel located in the middle of the lower part of the main control board, and cables.

2. POWER UNIT

Used as a primary power supply of the SON-9 is a mobile power unit, type APG-15, producing three-phase alternating current of 220 V, 50 c.p.s. and single-phase alternating current of 110 V, 427 c.p.s.

The general view of the power unit is shown in Fig.205.

The power unit is transported on a specially equipped truck, type ZIS-151, towing the radar station, and is designed to operate on the truck platform or on the ground.

The primary engine of the power unit is a four-stroke carburettor four-cylinder vertical internal combustion engine, type GAZ-MKB. The engine develops 22 h.p. at 1,500 r.p.m.

The power unit accommodates an A.C. synchronous generator, type MSA-72/4A, of 12 kW (at $\cos \varphi = 0.8$), 230 V, 50 c.p.s.

From the connector of the external distribution board the voltages are fed through a cable to the control cabinet contactors switching on the circuits of 50 and 427 c.p.s. To check the incoming voltages the control cabinet accommodates voltmeters.

The control cabinet houses the equipment protecting and switching the main control board lighting, ventilation and heating circuits.

The voltages of 50 and 427 c.p.s. from the control cabinet are fed to the control panel which serves for distributing power between consumers.

From the terminal blocks of the control panel the voltages are conducted to the main control board units, transmitter cabinet and separate loads consuming voltages of 50 c.p.s. (fan motors, amplidynes, lighting circuits, etc.).

In the absence of A.C. voltage the power supply for lighting circuits (emergency lighting) is a 6 V lead storage battery placed in a special case of the station cabin.

The SON-9 while operating on alternating current of 50 c.p.s. consumes about 7 kVA, and on alternating current of 427 c.p.s. about 3 kVA.

The total power consumed by the station is approximately 10 kVA.

50 c.p.s. voltage is used in the main to feed three-phase power motors and selsyns, and 427 c.p.s. voltage to feed the rectifiers of the station.

The voltage of increased frequency (427 c.p.s.) is intended for reducing the weight and dimensions of the power transformers and chokes.

To feed the SON-9 rectifiers the power unit APG-15 incorporates a converter, type ALA-3.5M-B2, used for converting 50 c.p.s. into 427 c.p.s. frequency. It consists of a three-phase induction motor operating on 220 V, 50 c.p.s. and a generator of increased frequency fitted on the same shaft with the motor. The generator rating: 3.5 kW (at $\cos \varphi = 0.8$), 115 V.

The power unit APG-15, is provided with distribution boards of the generator 50 c.p.s. and converter on which control, protective and starting equipments are installed.

The power unit is provided for supplying from a three-phase A.C., 220 V, 50 c.p.s. external supply. For this purpose the cable running from an external supply should be attached to terminals L_1, L_2, L_3, located on the unit feeder board and the rotary switch positioned on the same board set from position GENERATOR to position LINE.

.../3. BLOCK-DIAGRAM

3. BLOCK-DIAGRAM OF POWER SUPPLY SYSTEM

The simplified block-diagram of the station power supply system is shwon in Fig.206, while the key diagram in Fig.207 (See Album).

A.C. voltages of 50 and 427 c.p.s. produced by the power unit are conducted to connector Zw33-1 of the station right-hand external board through an eight-core power cable (See Fig.202, b).

4. CONTROL CABINET

The general view of the control cabinet is shown in Fig.208, key diagram in Fig.209.

The control cabinet accommodates the following equipment:

1. Contactor P31-1 (MAINS 50 c.p.s.) connecting 220 V, 50 c.p.s. mains to control buttons W31-1 (ON) and W31-2 (OFF) and contactor P31-2 (MAINS 427 c.p.s.) connecting 110 V, 427 c.p.s. mains to control button W31-4 ON and W31-5 OFF.

The contactors are provided with movable and stationary contacts (Fig.210). The movable contact shaft mounts a lever coupled to the movable part of the magnetic circuit of the magnetic starter.

When pushing button ON (W31-1 or W31-4) a voltage of 220 V, 50 c.p.s. is applied to the coil of the appropriate magnetic starter and the movable part of the starter magnetic circuit is attracted to the stationary one, the lever and the movable contact shaft being turned and all three movable contacts are simultaneously pressed against the stationary ones.

When pushing button OFF (W31-2 and W31-5) the supply circuit of the sucking coil opens and the movable contacts under their own weights come back to the initial position.

Each contactor is provided with interlocks which, upon operation of the contactor, shunt the ON-button. Therefore, after the contactor has been energized the ON-button may be released and the contactor will remain energized.

2. Thermal relays (P31-3, P31-6) in the 50 c.p.s. mains and relays, type TRW-40.5 (P31-4, P31-5), in the 427 c.p.s. mains used for protecting the supply circuits of the station from overlaods and short-circuits.

The relay heating elements composed of bimetallic plates mechanically act on the relay contacts which open and break the supply circuit of the appropriate contactor sucking coil when they carry current of higher than permissible value.

3. Rotary switches W31-7 (VENTILATION), W31-8 (MAIN CONTROL BOARD HEATING) and W31-9 (LIGHTING) to turn on or off the supply circuits of the appropriate loads.

4. Fuses B31-1 to B31-12 to protect the electric circuits from short-circuits. Each fuse consists of a replaceable link enclosed in a ceramic tube which on both sides is fitted with metal caps.

5. Socket-contacts G31-1 and G31-2 (220 V, 50 c.p.s.) for connecting a soldering iron and an oscillograph.

6. Meter M31-1, for counting operating hours, composed of a synchronous motor, type SD-2, a reduction gear and a roller computing device: the counter operates when both contactors (of 50 and 427 c.p.s. circuits) are energized.

7. Voltmeters Pp31-1, (50 c.p.s. VOLTAGE) and Pp31-2, (427 c.p.s. VOLTAGE), type E-421, to check the value of the voltage applied to the station.

8. Lamps Z31-1 and Z31-2 for lighting the voltmeter scales.

9. Button W31-3 SIGNAL for communication with the power unit by means of sound and light signalling using a special code. The code table is fixed to the front panel of the control cabinet. Pressing button SIGNAL (W31-3) closes the supply circuit of a horn and a pilot lamp located on the power unit.

5. CONTROL PANEL

The general view of the control panel is shown in Figs 211 and 212, while the key diagram in Fig.213.

The control panel carries the following equipments:

1. Magnetic starter P13-1 of the azimuth amplidyne and magnetic starter P13-2 of the elevation amplidyne with control buttons W13-1 (AZIMUTH AMPLIDYNE) and W13-2 (ELEVATION AMPLIDYNE), by means of which the amplidyne magnetic starters are switched on or off.

The movable contacts of the magnetic starter (Fig.214) are directly coupled to the movable part of the magnetic circuit (armature) which moves reciprocatingly up and down.

When the ON button of the magnetic starter is pushed a voltage of 220 V, 50 c.p.s. is fed to the sucking coil, the armature moves upward and the movable contacts are pressed against the stationary ones. When the OFF-button of the magnetic starter is pressed its contacts open under the weight of the movable contact system.

When the starter operates the ON button is shunted by the interlocks. To make the starter operation more reliable an additional interlock is installed in parallel with the main one.

2. Thermal relays P13-3, P13-4, P13-5 and P13-6 (type TRW-12) for protecting the amplidynes from overloads and short-circuits. The operating principle of the thermal relays, type TRW-12, is similar to that of the thermal relays, type TRW-305, located in the control cabinet.

3. Rotary switches: W13-3 (AA FIRE DIRECTOR) for energizing the selsyns of the AA fire director and searchlight, W13-4 SELSYN to feed voltage to the selsyns follow-up motors and relays; W13-5 (REFERENCE VOLTAGE GENERATOR) for energizing the motor of the reference voltage generator, W13-6 (DEHYDRATOR) for energizing the motor of the electric dehydrator.

.../4. Fuses

4. Fuses (ceramic) B13-1 to B13-14 to protect the electric circuits from short-circuits.

5. A fan with motor M13-1 providing ventilation of the main control board.

6. The main control board electric heater R14-1 for heating the air drawn into the main control board. It consists of two resistor sections located in the lower part of the board to either side of the control panel. The heater is switched on only at low ambient air temperatures.

7. Transformer Tr13-3 stepping down 220 V, 50 c.p.s. to 110 V for feeding the selsyn windings of the station follow-up motors and relays.

8. Transformers Tr13-1 and Tr13-2 to step up the reference voltage obtained from the reference voltage generator which is then fed to the azimuth and elevation tracking unit during automatic target tracking.

9. Selenium rectifiers D13-1 and D13-2 for shunting the elevation amplidyne control windings through limit switches, which retards the antenna in elevation in the extreme antenna positions.

10. Selector switch W13-7, resistor R13-1 and terminal blocks P113-9 and P113-10 for changing over to remote control from the PUAZO-6.

11. Connector Zw13-1 for connecting the target simulator to the station.

12. Terminal blocks P113-1 to P113-7 for connection with other units and components of the station.

6. CIRCUITS FED WITH A.C. OF 50 c.p.s.

220 V, 50 c.p.s. Circuits of Three-Phase Line

Voltage of 220 V, 50 c.p.s. (Fig.207) of the three-phase line is fed through the cable from the power unit via connector Zw33-1 (contacts 10, 11, 12) of the station external board to the control cabinet and is impressed on terminal blocks P131-4 (contact 4) and P131-5 (contacts 1, 2). Then it is fed to contactor P31-1.

With button W31-1 (ON, LINE 50 c.p.s.) pressed, the contactor operates and voltage through closed line contacts of the contactor and thermal relays P31-3 and P31-6 is applied to the fuse boards and terminal block P131-1 of the control cabinet.

From terminal block P131-1 220 V, 50 c.p.s. are fed to the control panel (to terminal block P113-1) and from there to the transmitter.

An A.C. voltage of 220 V, 50 c.p.s. of the three-phase line is used in the station to feed power motors.

Directly from terminal block P113-1 of the control panel the three-phase line voltage is fed through fuses W13-2, W13-3 and W13-4 to the fan motor (M13-1) of the main control board. Consequently, the fan is switched on simultaneously with application of voltage to the main control board through contactor P13-1 located in the control cabinet.

The cabin fan motor is fed from the control cabinet through fuses B31-4, B31-5, B31-6 and rotary switch W31-7 (VENTILATION). The fan is installed in the amplidyne cabinet and is switched on in summer time at high temperatures inside the cabin.

The azimuth and elevation amplidynes are energized by magnetic starters P13-1 and P13-2, located on the control panel.

Pressing button START W13-1 (AZIMUTH AMPLIDYNE) closes the supply circuit of the starter sucking coil, the starter operates and voltage through closed line contacts and thermal relays P13-3 and P13-5 is applied to the azimuth amplidyne motor (M34-1).

Pressing button START W13-2 (ELEVATION AMPLIDYNE) causes magnetic starter P13-2 to operate and a voltage of 220 V, 50 c.p.s. is applied through thermal relays P13-4 and P13-6 to the elevation amplidyne motor (M34-51).

Voltage to the automatic dryer motor is applied from the control panel through fuses B13-9, B13-10, B13-11 and rotary switch W13-6 (DEHYDRATOR).

The reference voltage generator motor M32-7 is connected to 220 V, 50 c.p.s. circuit through the slip rings of the antenna pedestal current

collector, rotary switch W13-5 (REFERENCE VOLTAGE GENERATOR) and fuses B13-12, B13-13 and B13-14 situated on the control panel.

110 V, 50 c.p.s. Circuits of Single-Phase Line

The windings of the selsyns of the station follow-up motors and relays are fed from 110 V, 50 c.p.s. single-phase line.

110 V, 50 c.p.s. are taken from the secondary winding of transformer Tr13-3 installed under the main control board.

The selsyns, follow-up motors and relays are connected to 110 V, 50 c.p.s. line through rotary switch W13-4 (SELSYNS) and fuses B13-7 and B13-8, located on the control panel. Via these fuses and terminal block Pl13-5 by-passing the switch the voltage of 110 V, 50 c.p.s. is applied to the rectifier supplying the field windings of the drive motors.

Thus, the motors are excited simultaneously with switching on the 50 c.p.s. line in the control cabinet.

The selsyns of the AA fire-director and searchlight are connected to 110 V, 50 c.p.s. line through fuses B13-5 and B13-6 and rotary switch W13-3 (AA FIRE DIRECTOR).

The main control board heater R14-1 is energized through fuses B31-7 and B31-8 and switch W31-8 (MAIN CONTROL BOARD HEATING).

Directly from output terminals of the control cabinet the power unit voltage of 220 V, 50 c.p.s. is applied through fuses B31-11 and B31-12 to connectors G31-1 and G31-2 of the control cabinet for connecting a soldering iron and an oscillograph. The voltage is then applied through fuses B31-9 and B31-10 and rotary switch W31-9 (LIGHTING) to lighting transformer Tr34-1, located behind the main control board.

Sketch of Lighting Circuits

The secondary winding of transformer Tr34-1 feeds 6 volts that are applied:

- to the control cabinet through terminal block Pl31-1 to lamps Z31-1 and Z31-2 for lighting the scales of the control cabinet voltmeters;

- to the receiving selsyn unit through terminal block P144-2 and switch W44-4 to lamps Z44-1 and Z44-2 for lighting selsyn scales;

- to the lighting board (Fig.215) to selector switch W35-5 (Fig.207) marked POWER UNIT - STORAGE BATTERY and through fuses B35-2 and B35-1 to terminal block P117-1.

With the switch in position POWER UNIT the station lighting lamps are fed with alternating current from transformer Tr34-1, while in position STORAGE BATTERY from the storage battery placed in a special case of the station cabin.

From terminal block P117-1 the voltage 6 V is conducted:

- through switches W35-1, W35-2, W35-3, W35-4, located on the lighting board and door interlock W35-6 shunted by switch W35-7, to cabin lighting lamps Z35-1, Z35-2, Z35-3, and Z35-4; through switch W17-1 to lamp Z35-5 located on the left-hand cabin wall at the telephone operator's table;

- to connectors G35-1 (on the lighting board) and G33-7 (on the external lighting board) to switch on a portable lamp and through switch W33-1 and W33-2 to the lighting lamps of the external boards.

Under blackout conditions switch W35-7 should be disconnected. In this case the cabin lighting is automatically switched off when opening the door.

7. CIRCUITS FED WITH ALTERNATING CURRENT OF 427 c.p.s.

110 V, 427 c.p.s. are fed through the power cable from the power unit to connector Zw33-1 of the station external board (contacts 60, 71).

From connector Zw33-1 voltage is fed to the control cabinet to contactor P31-2. Pressing button W31-4 (ON) causes the contactor to operate and a voltage of 110 V, 427 c.p.s. is applied to the control panel through two side line contacts, thermal relays P31-4 and P31-5 and terminal block P131-4.

Simultaneously the middle line contact is closed to feed the station operating time meter.

From terminal blocks P113-5 and P113-6 of the control panel the voltage of 110 V, 427 c.p.s. is applied to the amplifier unit of the automatic tracking channel (Zw1-6), the amplifier unit of the range channel (Zw2-4), power packs of the range and plan-position indicator systems (Zw5-3), the automatic tracking unit (Zw6-1) and to terminal block P125-1 of the transmitter cabinet for feeding the modulator-oscillator, driver and I.F. preamplifier unit.

For description of the supply circuit of the separate units and systems of the station see corresponding sections of the manual.

8. TABLES OF FUSES OF THE CONTROL CABINET AND CONTROL PANEL

The tables indicate the locations and rating of fuses.

Table of Fuses Located in Control Cabinet

Designation of fuses	Location	Fuse rated current	Notes
1	2	3	4
B31-1 B31-2 B31-3	Spare	25 25 25	Located from right to left on the vertical panel
B31-4 B31-5 B31-6	Supply circuit of cabin fan motors	15 15 15	Located from right to left on the vertical panel
B31-7 B31-8 B31-9 B31-10 B31-11 B31-12	Supply circuit of main control board heaters Lighting supply circuit Oscillograph, soldering iron circuit	15 15 5 5 15 15	Located from left to right on slanted panel

.../Table of

Table of fuses located on the Control Panel

1	2	3	4
B13-1	Spare	5	
B13-2	Supply circuit of control	5	
B13-3	panel fan motor	5	
B13-4		5	Located
B13-5	Circuit supplying anti-	5	from left
B13-6	aircraft fire director and searchlight	5	to right on
B13-7	Supply circuit of selsyns,	25	panel
B13-8	follow-up motors and relays	25	
B13-9	Supply circuit of automatic	10	
B13-10	dryer motor	10	
B13-11		10	
B13-12	Supply circuit of reference	5	
B13-13	voltage generator motor	5	
B13-14		5	

.../Chapter 10

Chapter 10

AUTOMATIC AIR DRYER (DEHYDRATOR)

1. GENERAL

The automatic dryer (dehydrator), type AD-220T, is designed to dry the air obtained from the atmosphere and to deliver it under low pressure to the antenna-feeder system.

The dryer AD-220T capacity depends upon the output air pressure:

Air pressure at the dryer outlet, kg/sq.cm.	0.2	2.4
Air consumption, lit/min.	22	10

The air humidity at the dryer output depends upon the humidity of the atmospheric air, its consumption by the dryer and the number of hours in operation.

The dryer is fed with a three-phase current of 220 V, 50 c.p.s. and consumes about 1.2 kW. The dryer weight is about 105 kg, and dimensions: length 458, width 640, height 562 mm.

2. CONSTRUCTION AND OPERATION

The general view of the automatic dryer is shown in Fig.216. The key and wiring diagrams are presented in Figs 217 and 218.

Dryer Construction

All parts and units of the dryer are mounted inside a metal frame.

The front panel carries dryer controls (Fig.216) whereas on the back are mounted the parts of the controls, their wiring and other elements (Figs 217 and 218) whose name and purpose are given below.

Switch 35 (Fig.217) is designed to turn on the dryer, and lamp 40 to indicate that the dryer is energized. Lamps 33 light up indicating which of the drying chambers is being restored.

A time relay with motor 38 controls the operation of the dryer. Magnetic starter 37 controls the operation of motor 1 of compressor 2.

Pressure gauge 20 reads pressure in the line.

Moisture indicator 21 is a glass tube containing silica gel (silicic acid $S_1O_2.NH_2O$) impregnated with cobalt salts. The silica gel changes its colour depending on the humidity of the air drawn through it.

Pressure governor 19 enables the air pressure to be varied manually at the dryer output. After each adjustment the governor handle should be locked with a nut.

Needle valve DEW POINT 17 makes it possible to decrease the amount of the air dryer's output and thereby to lower the "dew point" temperature.

The left- and right-hand walls carry solenoid valves (10, 11 and 28, 29) controlling the air flow leaving the drying chamber. The valve proper is a tip press-fitted into the core of the electromagnet.

Drying chambers (7, 25) are intended for drying the air forced through them. Each chamber contains 3 kg of silica gel (silicic acid $S_1O_2.NH_2O$) and is fitted with a heating element (6, 24), a temperature relay (8, 26) and a filter (9, 27).

The heating element (6, 24) is a bent tube which accommodates a heating spiral buried in quartz sand.

The temperature relay (8, 26) is used to limit the temperature rise in the drying chamber to +230° by breaking the supply circuit of the heater. Its operation is based upon the use of various linear expansion coefficients of brass and invar.

Located on the bottom of the dryer housing are step-down transformer 39, air collector 16 with return valve 15 and filter 18.

The air collector with return valve is designed to smooth the pulsation of the air flow and to reduce the number of the compressor starts when the line is hermetically sealed.

To ensure normal operation of the return valve the rubber used in it should be elastic and glossy and without surface irregularities.

The dryer base mounts motor 1 driving compressor 2. The compressor, diaphragm type, draws in the atmospheric air and delivers it under pressure through the drying chambers to the feeder system and to the drying chamber which is in the restoration process (to blow it out). The employment of diaphragms in the compressor ensures against penetration of oil fumes in the compressed air. The compressor is driven by the motor through a belt transmission.

Located under the base is a cooler, ribbed tube 3, designed to cool the compressed air entering the drying chamber.

To protect the air system of the dryer from excessive pressure and to switch off the compressor at the five-hour cooling cycle use is made of pressure relay 12 which consists of a transmitter, a servo mechanism with two bleeding valves and a contact device with a magnet. The transmitter is a diaphragm-type device picking up the line air pressure.

The dryer operation (closing of the dryer electric circuit contacts) is controlled by means of the time relay (Fig.217). Fig.217 and the relay diagram presents the circuit diagram of the dryer and the time relay cyclogram.

The time relay is a box accommodating a shaft with cams which close and open the contact plates while the shaft is rotating. The shaft is driven by motor 38 through a reduction gear.

The cams (their crests) are set to corresponding divisions by the limb depending on the dryer work cycle (time relay work cycle) and are pinned to the shaft: the first cam is set to division 7, the second to zero division, the third to division 12, and the fourth to division 19.

<u>Note</u>: The cams are checked for proper setting as follows: when the shaft is turned from a position corresponding to zero division to a position corresponding to 7 (on the scale) contact plates 1, 2 and 3 should be closed. In the position

.../corresponding to

corresponding to 7 contact plates 1 and 2 open, contact plate 3 remains closed until the shaft is turned to a position corresponding to 12.

At figure 12 contact plate 3 opens, whereas plates 4, 5 and 6 close.

At figure 19, contact plates 5 and 6 open, while plate 4 remains closed until the shaft is turned to figure 24.

The shaft being further rotated, the cycle is repeated.

The time relay contact plates are coloured as follows: the first plate is yellow, the second is green, the third is blue, the fourth is yellow-blue, the fifth is black and the sixth is red.

To facilitate wiring the dryer circuit wires have the same colour coding as the time relay. This coding is presented on the wiring diagram (See Fig.218).

Dryer Operation

Air drying is based on the active moisture-absorbing properties of silica gel.

When the dryer operates for a long period of time the drying chambers operate alternately: while one chamber is engaged in air drying for a period of 12 hours, the other chamber is restoring silica gel by calcination at a temperature of 200° for seven hours with subsequent cooling for five hours.

Let us consider the dryer operation consulting the diagram presented in Fig.217 where the active chamber is represented by chamber 7.

When the motor is energized and one of the silica gel chambers operates continuously the atmospheric air is admitted from compressor 2 to cooler 3 and bleeding valve 13 of pressure relay 12.

At the coil outlet the air flow takes two channels: one runs to chamber 7 in which air is dried (absorbtion), the other to chamber 25 where silica gel is restored.

The air flowing through the first channel passes via return valve 4, enters drying chamber 7 (during absorbtion process) and gives up its moisture to silica gel particles. The dried air passes through filter 9, where it is purified through solenoid valve 10, filter 18, return valve 15, air collector 16, needle valve 17, pressure governor 19, moisture indicator 21 to the feeder line. The air pressure in the line is measured by pressure gauge 20.

The air flowing through the second channel is admitted through return valve 22, to drying chamber 25 (during the restoration process), captures water vapour formed due to heat dissipation from heating element 24. Then the air passes through filter 27, solenoid valves 28 and 29 and escapes through throttle sleeve 31 in solenoid valve 29.

This process takes seven hours. During this period the compressor motor operates continuously, (and one of the green lamps burns). By the end of the process silica gel in drying chamber 25 is restored and airpipes running from chamber 25 are completely dried by the hot air flowing through them. Solenoid valve 29 closes, heating element 24 is cut off and the atmospheric air goes on flowing through drying chamber 7 for five hours. During this time drying chamber 25 cools down to the ambient temperature.

During this same period silica gel in drying chamber 25 is being restored. Thus the working cycle of silica gel restoration takes 12 hours.

During the five-hour cycle the compressor motors and the time relay operate intermittently.

The operation of the compressor motor is controlled by the pressure relay as follows:

If the pressure is beyond the permissible value the diaphragm of pressure relay 12 sags and through a pusher acts on the servo mechanism against the force of adjusting springs. In this case the spring shifts the lever to the extreme position. The lever side projections press the

.../pushers of

pushers of the bleeding valves and open them. The air from the compressor mains and the air pipe passes to the air collector. Simultaneously the lever acts on the contact device breaking the supply circuit of the compressor motor. As soon as the pressure on the diaphragm falls to the set value the relay mechanisms will come back to the initial position again and the supply circuit of the compressor motor is closed.

The relay operation order described above takes place only during the five-hour cycle.

The time interval between the compressor switchings on depends upon the hermetic sealing of the line. The better the sealing the longer the cut-off period. Therefore, the five-hour cycle may take several days (if the air leakage is inconsiderable), i.e. as long as the total duration of all compressor switchings on makes up five hours.

During the seven-hour cycle the relay controls the air pressure in the line with the compressor operating continuously.

When 12 hours elapse the time relay switches the solenoid valves so that the process described is repeated for chamber 7 (chamber 7 starts to restore silica gel while chamber 25 begins operating). The complete cycle accompanied by switching over chambers 25 and 7 is accomplished during 24 hours of the dryer operation.

Chapter 11

RADAR EQUIPMENT TRAILER

1. PURPOSE

The SON-9 equipment trailer (Fig. 219) is designed for the accommodation of the equipment, instruments accessories and the operating personnel. It is a low-down four-wheel trailer consisting of a cabin and chassis with independent front and rear-wheel suspensions.

The trailer is transported by a towing vehicle (truck ZIS-151) on main and earth roads at a speed of 45 and 25 km. per hour respectively. The turning radius of the truck and trailer taken from the treadmark of the trailer outside wheel is not less than 10 m. The tread of the front and rear wheels is 1980 mm, the wheel base is 3500 mm and the clearance is 330 mm.

2. CHASSIS

The trailer chassis consists of a frame, front and rear suspensions, a brake system, a drawbar and a turning gear.

Frame

The frame (Fig. 220) consists of two side members 1, seven cross members 2, two box-shaped bars 3, six side bars 4 and two side angle-bars 5. The frame takes the load from the weight of the cabin and all the equipment. It also takes the torques of the torsion-bar suspension, braking and inertia forces during turning and movement of the trailer.

Welded to the ends of the side members are wheel suspension brackets 6. The side members and bars mount the trailer floor. On the left in the frame is located box 7. Bracket 8 which attaches the drawbar by means of a pivot is welded to the front cross member of the frame, while pintle hook 9 to the rear one.

In four frame angles, where the box-shaped bars are fixed to the side bars are welded gusset plates 10 with holes for securing jacks.

Construction of Front and Rear Suspensions

To keep to a minimum dimension of the trailer in height, and to ensure

maximum clearance, better cross-country capacity and absorbing of shocks use is made of independent, torsion-bar, rigid front and rear suspensions with double-rod system.

The front wheel suspension (Fig. 221) consists of torsion bar 1, torsion cylinder 2 and arm 3 secured in bracket 4 which is welded to the frame side member. Arm 4 /presumably mistake for 3/ of the torsion bar is coupled with its one end to steering knuckle 5 by means of a king pin, the other end is fitted on the splines of torsion cylinder 2 rotating in the bushings of frame bracket 4. The torsion cylinder houses torsion bar 1 with splined ends. One end is fixed in the torsion cylinder, the other in the sleeve welded to frame bracket 4. The torsion bar is provided with caps 6 secured on both ends by bolts. The caps ensure that the torsion bar and cylinder are held in place while the trailer is in motion.

Loads in the wheel suspension are transferred as follows:- torsion arm-cylinder, torsion bar-frame bracket.

The construction of the rear suspension is similar to that of the front suspension with the exception that the rear wheel axle is welded to the torsion arm. The torsion bars are also similar in design, the difference being in the direction of torsion indicated on the end face of each bar by means of an arrow, namely: front left and rear right, front right and rear left. Except for this the torsion bars are interchangeable. This is also the case with the frame brackets.

The torsion arms front and rear that are fixed to cylinder 2 are provided with splines equal in size. The torsion cylinders are also interchangeable.

Construction of Wheel Hubs and Brakes

All the four trailer wheels carry hubs, brakes, brake drums and chambers for the front wheels of truck ZIS-150. The wheels are disc-type tyres with detachable rims with locking rings. The low-pressure tyres (balloons), size 10.00 x 20", consist of a beadless twelve-ply tyre, an inner tyre and a rim band. The maximum pressure in the wheel tyres is 5 kg/sq.cm. while the minimum one is 3.5 kg/sq.cm. The wheel brakes are pneumatic block brakes

actuated from the truck.

Wheel hubs. Brake supporting disc 29 (Fig. 222) on the front wheel is attached to the flange of steering knuckle 12 (on the rear wheel - to the flange of the steering arm). The end of the steering knuckle is hinged to torsion arm 28 by means of king pin 22. The latter is fixed in the torsion arm by wedge pin 21.

The steering knuckle bushings 18 are freely set on the king pin. The bushings are provided with oil grooves through which oil is delivered from the lubricators screwed in the knuckles. From top and bottom the knuckles are covered with cap 17 having gaskets. Each cap is secured with two bolts.

To minimize friction between the torsion arm and the knuckle lower projection the projection recess accommodates a radial bearing composed of two rings (23, 24); the lower ring, bronze-graphite, is tightly fitted in the knuckle projection recess and is turned together with it relative to the upper ring (23). The friction surfaces are lubricated with oil delivered from the oil groove of the knuckle lower bushing. To protect the bearing from dirt and to retain grease, the bearing is provided with a gland (on the upper ring).

For the elimination of the axial play of the steering knuckle on the king pin use is made of adjusting shims 20 fitted on the king pin between the torsion bar boss and the knuckle upper projection.

Hub 5 of the front and rear wheels is set on the axle in two taper roller bearings 11 and 13. The bearings are adjusted by nut 10 retained by locking ring 9 and locking nut 8 with lock plate washer 7. The hub flange carries eight pins 3 which mount wheel disc 2. The pins of the left wheel are provided with left-hand thread, the right wheel with right-hand thread.

Brake drum 1 is bolted on to the inside of the hub.

Note: The nuts of the screws securing the drum and the wheel locking pins are prevented from working loose by punching the threads.

On the outside the hub is covered by a cap (on a cardboard gasket) and secured with bolts.

Note: In trailer of earlier design two holes fitted with threaded bungs 39 were placed in the cap for filling the hub with oil.

To ensure against penetration of oil from the hub to the brake, gland 14 is provided clamped between the inner bearing and the flange of the steering knuckle. The gland consists of a felt ring enclosed between two stamped metal holders and is kept from turning by a stand press-fitted into the gland ring which enters the opening of the steering knuckle flange.

Moreover, to protect the brake from penetration of oil through the gland, oil separator 15 is secured to supporting disc 29. The oil removed from the rotating hub to the oil separator escapes outside through a hole between knuckle 12 and brake supporting disc 29.

The wheel bearings are so adjusted that the wheel rotates freely without run-out and the hub axial play is not perceptible.

To ensure proper "road-holding" by the trailer and to prolong the service life of the tyres the front wheels and the king pin are set relative to the trailer supporting surface at the following angles:

- Wheel vertical axis inclination (camber) is 1°.
- Front wheel toe-in is 0.5°.
- King pin inclination is 8°.

Deviations in setting the wheels and the king pin from the specified values of angles reduce the service life of the trailer chassis and decrease stability on the move.

Brakes. The wheel brake mounted in drum 1 (Fig. 222) has two cast iron blocks 30 set on pins 42. Part of the pin which carries the block is eccentric relative to a neck secured in bracket 43. Such a design permits, by turning the pins, to shift the blocks relative to the brake drum while adjusting the brake. The other ends of the blocks are pressed by a tension spring 31 to expansion cam 33. To the blocks are attached two straps 32 of asbestos material.

The cam shaft is set in bracket 36, bolted to supporting disc 29. The brackets accommodate lubricators 35 to oil the expansion cam shaft. Between the shaft and bracket of the supporting disc washers are fitted on the shaft. The end of the splined cam shaft mounts arm 37 coupled by means of a

pin to the fork of the brake chamber rod 44.

To adjust brakes, arm 37 accommodates worm 38 held in place by lock 45, the worm engaging worm gear 40 set on the splines of the expansion cam shaft. Turning the worm with a wrench by the square head causes turning of gear 40 together with the shaft whose cam separates the blocks, thus decreasing the gap.

Brake System

The brake system is used for braking the trailer during transportation as well as for emergency braking if the trailer breaks loose from the truck. In this case the assembly automatically brakes the trailer until it stops completely.

The brake system of the equipment trailer operates in conjunction with the truck pneumatic brake assembly.

The brake system includes: brake chambers (for each wheel), a compressed air storage tank, an air distributor, a shut-off cock, a connecting head, air lines and fastenings.

Brake chambers. The brake chambers of all the wheels are similar in design. Rubber diaphragm 2 is clamped by bolts between stamped body 1 (fig. 223) and cover 3 of the brake chamber. The diaphragm is pressed towards the cover by springs 6 and 7 set between rod heel 4 and the chamber body. Fork 10 screwed on the rod end coming out of the chamber is coupled to arm 11 fitted on the shaft 16 of the expansion cam.

The threaded hole of the chamber cover receives pipe connection 5 of the flexible hose to connect the chamber with the air distributor.

When brakes are applied the compressed air is admitted to the compartment between the chamber cover and the diaphragm and by deflecting the latter displaces the rod, thus turning arm 11 of the brake expansion arm. The rod end describes an arc, that is why it is fitted in the hole of the chamber body with a sufficiently large clearance to ensure against binding. Fitted on the rod is washer 8 pressed to the body by spring 7. The washer protects the chamber from dirt.

Displacement of the diaphragm during braking is determined by the value

of the clearance between the blocks and the brake drum and the wider the clearance the greater it will be.

Pins 9 serve to secure the brake chambers to the supporting discs.

The compressed air storage tank is a thick-walled reservoir of 35 lit. capacity. To the front bottom of the tank is attached a hose running from the air distributor. To drain the accumulated water and to let out the compressed air a special cock is provided.

The tank is secured to the left-hand side member of the chassis frame by two straps.

The air distributor (Fig. 224) consists of body 1 and two covers 2 and 3 clamped by bolts. The air distributor accommodates rod 4 with piston 5. The rod mounts inlet and outlet valves (6 and 7).

Shut-off cock and air lines. The shut-off cock is used for shutting the brake system when it is disconnected from the truck. The air lines are metal tubes and high-pressure hoses.

Brake system functioning. Braking is done with the help of compressed air stored in the air tank.

The brake system is coupled through air brake connection 8 to the truck air line (Fig. 225, a).

The compressed air is forced by the compressor through air main 12, shut-off cock 14 and metal tube 13 to the pipe connection in the cover of air distributor 9, fills up compartment A and while moving rod 4 upward, presses (shuts) inlet valve 6 to the seat, opens outlet valve 7, bends back the collars of piston 5, and then through compartment B is admitted to the storage tank, thereby maintaining constant excess pressure.

At this time chambers C and D and consequently brake chambers 11 are vented to the atmosphere and, therefore, have no influence whatever upon the arms of the expansion cams of the brakes (chamber 11) and the wheels rotate freely.

When the driver presses the brake pedal air main 12 (Fig. 225, b) of the trailer communicates with the atmosphere, the compressed air escapes from

compartment A, while the compressed air in tank 10 by acting on piston 5, moves rod 4 downward and simultaneously opens inlet valve 6, shuts outlet valve 7 and presses the collars of piston 5 to the walls of air distributor body 1.

Thus the compressed air is admitted from tank 10 to compartment 3 and through inlet valve 6, compartment D and air lines enters the brake chambers (Fig. 223) where it acts on diaphragm 2, pushes rod fork 10 and through the medium of arm 11 turns shaft 16 of the expansion cam taking apart the brake blocks and pressing them to the brake drum that rotates together with the wheels. This results in wheel braking.

The brake pedal released, the air supplied by the truck compressor enters compartment A again (because part of the air from the air tank is consumed and the pressure in compartment B is lower than that in compartment A) and moves the rod with the piston and valves upward (Fig. 225, c). In this case valve 6 shuts, valve 7 opens, the piston collars are bent back and air is forced through compartment B to the air tank, thereby creating the normal working pressure.

When valve 6 disconnects compartment D from the air tank, then it is vented through outlet valve 7 and compartment C to the atmosphere. In this case the compressed air escapes from the brake chambers through compartments D and C to the atmosphere, the diaphragm of the brake chamber is returned to the initial position and turns the expansion cam shaft in the opposite direction; the brake blocks come together by the action of the springs and thus the wheels are unbraked.

Drawbar and Turning Gear

For towing the trailer is provided with drawbar 4 (Fig. 226) swinging in a horizontal plane and rod 1 rocking in a vertical plane.

One rod end that terminates in eye 2 is fitted during transportation on the truck towing hook. The other end is pivotally attached to drawbar 4 which is also hinged in bracket 5 welded to the frame. Pins 6 of the front wheel turning bars are welded to the drawbar boss. Therefore the drawbar,

turning bars, steering knuckle arms and front wheel steering knuckles constitute an integral kinematic system.

To ensure straight motion of the trailer when pulled back by the truck the drawbar is provided with lock 7 fitted in holder 8.

To set the drawbar with the rod in the rest position the drawbar is furnished with eyes and pin 9.

The turning bars of the trailer (Fig. 227) are of a rod type. One end of the bars terminates in a shackle to engage the drawbar pin, the other end is screwed on end piece 11 secured by bolts 9. The cylindrical seats of the bar end pieces take ball pins 10 of the arms of steering knuckles 7. The pin head is held in position by two steel slide blocks 4. The inner spherical surface of the blocks is eccentric relative to the outer cylindrical surface.

The holes of the thicker parts of the block take the spring (3) ends brought together, the spring tending to straighten moves in the blocks between the pin head and the cylindrical surface of the end piece seat. In this case the ball pin axis is displaced perpendicular to the bar axis, which provides constant bar length at any wear of ball pin and slide blocks. Plug 2 with a cotter pin slot is screwed in the end piece seat.

When assembling the hinge the plug should be driven right home, then unscrewed 1/4 of 1/2 of a turn and cotter-pinned. Where the pin projects from the end piece washer 5 of the gland with a metal holder is installed. The washer grips the pin tightly and the spring (6) is pressed through the holder to the bar end piece. The swivels are oiled through lubricator fitting 8.

3. CABIN CONSTRUCTION

The cabin consists of a frame welded to the chassis frame, inner and outer plating, doors, hatches and windows necessary during the operation of the station.

On the inside the cabin is lined with plywood, on the outside with steel sheets. Placed between them are thermo-insulating mats made of glass fibre. The floor is made of boards which are covered with linoleum.

The right-hand body wall is provided with an entrance door, a window

and a ventilation hatch, the left-hand wall with a window, storage battery cabinet and openings for a stove pipe and air inflow to the stove and a distribution supply board.

The rear wall is provided with a two-leaf door with a level shelf for installation and checking of the equipment, while the front wall with a hatch for the air dryer. The leaves of the rear hatch are provided with cramps to facilitate climbing to the cabin top.

4. HEATING SYSTEM

When the station is operating the cabin is heated by an electric stove and the equipment itself; if the station is inoperative, by a special wood-burning stove placed inside the cabin.

The stove (Fig. 228) consists of fire box 1 with a hatch for loading fuel. The hatch is closed with door 2 with a latch and reflector 3. The bottom of the fire-box mounts grate 4 and body 5 of the air feed regulator in assembly with fire-box shell 6. The slots of the air feed regulator body accommodate the regulator throttle terminating in knob 7. To increase draught pull the throttle out and vice versa.

The fire-box shell 6 is mounted on a base 8 bolted on to the cabin floor. Placed between the base and the floor is a steel sheet. Partition 9 divides the base into two parts: ash pit 10 (upper) and box 11 for drying and keeping wood. Air feed tube 13 is welded into the upper chamber of the base. Placed between fire-box 1 and shell 6 is thermoinsulating asbestos packing 14.

From the fire-box the products of burning pass to air heater 15 leaving heat with ribbed pipe 16 of the air heater and by-passing damper 17 flow through exhaust pipe 19 covered with protective jacket 20 to stack 22 and through deflector 23 escape outside.

Damper 17 of the air heater pipe should be opened and shut according to inscription (OFF -- ON) at handle 18 held in the required position by a wing nut.

The plywood cabin wall is separated from the stove by protective steel

plate 21 with asbestos packing. The set of stove accessories include a poker and a scoop kept in a wooden box.

When the stove is not fired the funnel should be fastened on the cabin top, and air feed and smoke discharge vents tightly shut with covers 24, 25.

5. VENTILATION SYSTEM

To provide normal temperature conditions when the station is operating, the cabin is provided with a ventilation system consisting of a forcing fan and a natural draught fan. The forcing fan (with a motor rated at 75 W, 220/127 V and 2800 r.p.m.) is mounted on the cabin front wall in the left-hand upper corner. The natural draught fan is located on the right-hand cabin wall. The shutter of the fan vent can be opened manually when necessary.

Fresh air drawn by the forcing fan passes through a strainer located in the space in front of the fan propeller and is admitted to the fan housing and through two vents, manually operated, to the cabin. In this case the heated air escapes through the natural draught fan.

If the cabin should be supplied with maximum amount of air open both vents of the forcing fan. When the forcing fan is inoperative air is admitted to the cabin through the natural draught fan vent.

6. AUXILIARY EQUIPMENT

The auxiliary equipment includes: two swivel chairs placed inside the cabin in front of the main control board, folding desk, chair and telephone desk at the left-hand cabin wall near the stove, a fire extinguisher, a case for technical papers, a tool box, a can with rubber cement etc.

7. JACKS

Levelling of the trailer and unloading of the wheel suspension during the preparation for storage is carried out by means of four jacks which are located in the cabin.

Each jack (Fig. 229) consists of column 1 with supporting flange 2 by means of which the jack is installed on the cabin floor and through four openings is secured to the trailer frame. Fastened to the column by four bolts is body 3 provided with an inspection port covered with a cap. The

column accommodates tube 4 on which nut 17 of jack screw 5 is retained with the help of a nut and a key.

Tube 4 has a longitudinal guiding groove and terminates in supporting plate 6, which due to slipping in the round bar guide may rest on the inclined surface with its entire face. Tube 4 houses jack screw 5 which mounts larger bevel gear 7 meshed with smaller bevel gear 8 on the shank of which handle 9 is fitted.

When rotating the handle drive is transmitted through a pair of bevel gears (7 and 8) to the jack screw, which, while rotating in bearings, moves translationally tube 4 together with supporting plate 6.

To prevent the tube from turning, the column mounts stop 10, which enters the tube longitudinal groove. In the travelling position and after levelling handle 9 is removed and placed between the column 1 and leaf spring 11. For rapid lifting or lowering of the supporting plate the jack is provided with idle running handle 12. In this case the jack screw is rotated by a pair of spur gears (13 and 14) positioned in cap 15. The jack rotating parts are mounted in ball bearings.

The trailer levelling is checked by level 16 located on cap 15.

When levelling the trailer wooden pads should be placed under the supporting plates of the jacks.

When the station is being prepared for transportation the supporting plates should be lifted as far as they will go.

When checking the jack levels use is made of a horizontal plate placed on the floor at the trailer entrance door.

8. LIGHTING AND SIGNALLING SYSTEM

The cabin is lighted with four ceiling lights (Fig. 230) fed by a storage battery or from a 6-V circuit. The lights are changed over to the required supply by two-pole switch W35-5 (Power unit - storage battery). Each ceiling light is provided with its own switch (W35-1 to W35-4).

The ceiling light supply circuit is provided with fuses (B35-1, B35-2) with link for 6 A (type PR-1). Door interlock W35-6 is designed to switch

off the cabin lighting when the door is opened (for blackout purposes). The interlock may be turned off by switch W35-7 situated near the door. The circuit includes a coupling socket, two leads to the instrument board lamps provided with switches and a lead to the desk of the head of the station.

The cabin licence plate light and stop light (Fig. 231) are powered from the truck. The rear light circuit is coupled to the truck circuit by means of a connector. In addition to the electric lighting the cabin is provided with red reflectors (two reflectors on each cabin wall).

.../Chapter 12

Chapter 12

ECHO BOX

1. PURPOSE

The echo box (Fig.232) is designed for checking the operation of the radio-frequency part of the station and for its tuning.

The echo box is used for:

- measuring frequencies of the transmitter magnetron oscillator and the receiver microwave heterodyne;

- relative checking of the transmitter output power;

- analyzing the frequency spectrum of the radio-frequency pulse generated by the magnetron;

- checking the operation and tuning radio-frequency components of the station.

The key diagram of the echo box is presented in Fig.233.

2. OPERATING PRINCIPLE AND CONSTRUCTION OF ECHO BOX

The echo box is a combination of a resonant cavity and an indicator device (Fig.233).

The resonant cavity is a steel cylinder, 15 cm. in diameter and 14 cm. in length.

In order to reduce losses the inner surface of the cylinder is polished and silver-plated. Such a cavity circuit is similar in its electrical properties to an oscillatory circuit with lumped capacitances and inductances which has a very high quality factor.

The resonance frequency of the cavity circuit depends on variation of its volume. The volume of the echo box cylindrical cavity is varied by a tuning plunger which is moved along the cylinder axis with the help of knob 5 (Fig.232). The plunger travel equals 40 mm. A 1.5-mm clearance is provided between the cylinder walls and the plunger.

.../When rotating

When rotating knob 5 of the echo box clockwise the cavity volume increases and the resonance frequency of the echo box decreases and vice versa. A definite resonance frequency corresponds to each fixed position of the plunger, i.e. a definite cavity volume. The plunger position is indicated on scale 4.

The travel of the cavity plunger within 25 mm covers the station operating frequency band 2700 to 2860 Mc/sec.

The echo box cavity has high quality factor, therefore its resonance curve is rather sharp. This makes it possible, by using resonance frequency versus plunger position calibration curve, to measure exactly the frequencies of the transmitter and microwave heterodyne and to determine the frequency spectrum of the ultra-high frequency pulses produced by the magnetron.

The echo box antenna consists of a horn with a dipole. The horn mouth is hermetically sealed with a plastic cover.

Antenna 1 (Fig.234) is secured to supporting tube-rod 2 with bracket 3. The tube-rod accommodates radio-frequency coaxial cable 4 which t terminates in a coupling loop entering the circuit cavity.

The ultra-high frequency energy radiated by the station antenna induces E.M.F. in the echo box antenna. This E.M.F. is conducted through the coaxial cable to the echo box cavity circuit with the aid of the coupling loop.

When tuning the cavity to a frequency approximating that of the oscillations radiated by the station antenna, damped oscillations of the same frequency are excited in the echo box circuit, whose amplitude value is the greater the more accurate the cavity circuit is tuned to the transmitter frequency.

The echo box cylinder hole incorporates another coupling loop whose plane is crossed by magnetic lines of force of the radio-frequency electromagnet field. This field induces variable E.M.F. in the loop. In

.../turn this

turn this E.M.F. influences the echo box indicator device composed of a crystal detector (Fig.233), capacitors C-1 and C-2 and microammeter Pp-1 which reads D.C. component of the detector rectified current.

Connected in parallel with the microammeter by means of switch W-1 is shunt R-1 reducing the instrument readings 10 times.

The magnitude of current flowing through the indicator device is proportional to the value of the radio-frequency variable E.M.F. induced in the echo box cavity circuit, which in turn depends upon the power of the transmitter pulses radiated by the station antenna.

If measurements are always taken by the echo box in the same conditions the echo box indicator readings will characterize, in a certain extent, the station transmitter power.

In this case it should be taken into account that the microammeter readings are also dependent upon the quality of the echo box cavity and the quality of the crystal used in the echo box indicator device. Therefore no final conclusions should be drawn as to the transmitter power as measured by the echo box microammeter.

The radio-frequency energy transmitted by the antenna induces radio-frequency oscillations in the tuned cavity of the echo box, their amplitude increasing during the action of the transmitter voltage pulses.

Upon cessation of the transmitter pulse the oscillations in the echo box continue but gradually damp (Fig.235). This damping is caused by losses in the cavity circuit and in the resonator indicator device circuit.

Besides, part of energy is radiated by the antenna back into space. This energy picked up by the station antenna converted and amplified in the receiver, is furnished to the range indicator.

The echo box radiates comparatively great power, therefore its signal is displayed on the range indicator as a wide pulse having a flat top, due to the receiver saturation.

.../The time

The time interval between the beginning of the transmitter pulse and a spot where the amplitude of the pulse radiated by the echo box and furnished to the station receiver input fades into the background noise (on the range indicator) is termed oscillation or ringing time (Fig.236).

The ringing time may be determined by measuring on the station range indicator the range to the spot in which the echo box signal disappears in the noise (Fig.237).

The accuracy of tuning of the station radio-frequency component may be judged by the ringing time.

With the optimum tuning of all the station radio-frequency components the ringing time is maximum.

When using the echo box take into account that the ringing value may prove low due to some other factors which are not connected with the operation and tuning of the station radio-frequency components.

These factors may be: deterioration of the echo box cavity quality with time or as a result of considerable temperature rise in the station cabin, inaccurate aiming of the station antenna at the echo box antenna, improper contact in the echo box junction cable connectors, etc.

The resonant-cavity circuit and the indicator device are mounted on a rigid steel plate. The echo box is secured to the left-hand cabin wall near the transmitter:

The echo box cable is brought out through an opening in the cabin wall. It terminates in a connector to which is coupled connector 5 (Fig.234) of the echo box antenna cable.

Located beside the echo box on the cabin is a calibration curve which is used to determine the resonant frequency of the cavity circuit depending upon the plunger position in the cylinder.

The block diagram of the echo box operation is shown in Fig.239.

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SECRET

POLAND/USSR

MILITARY/AIR

50X1-HUM

Text of a Manual: "Gun-Laying Radar SON-9"

PART II

OPERATION OF THE SON-9 STATION

WARNING

1. Be careful when inspecting, tuning and repairing live units as in some cases even 110, 220-V circuits may prove dangerous to life. All operations in energised units must be done with your right hand; the left hand must be kept behind the back.

2. Exercise special care when inspecting the transmitter system, power pack of the range measuring and plan-position indicator systems as they are under 500; 700; 1400; 1700; 4000; 5000 and 25,000 volts. Alterations of any kind in the interlocking system when inspecting these units under high tension are strictly forbidden.

3. When replacing the tube of the plan-position indicator put on goggles to protect your eyes in case it bursts.

4. Before switching on the station make sure that there are no exposed current-conducting elements.

5. Do not replace blown fuses by those rated for heavier currents. When replacing fuses use the tongs located on the inside of the control panel door.

6. When operating the antenna pedestal switch off the selsyn, for which purpose set switch SELSYNS (W13-4) situated on the control panel in position OFF; set switch INTERLOCKING (W12-2) located on the front panel of the antenna control unit in position OFF.

50X1-HUM

7. The repair of any station elements if they are switched on is forbidden.

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8. When using extension cables switch on the units only after making sure that there are no short circuits between the energised units and the chassis.

9. Do not remove or insert live units.

10. Before switching on the station check for proper setting of knobs and switches on the units.

11. When switching on or off the station follow the sequence described in Part II, Chapter 2.

12. When turning the antenna manually take it by the reflector frame. Do not turn the antenna by holding on to the reflector as this may damage the paraboloid.

13. When doing maintenance work use standard tools only. Be careful, when working in the magnetron compartment with steel tools, not to knock the poles of the magnet as this may cause deterioration of its magnetic properties.

14. When heating the stove do not leave it without supervision.

15. Before switching on the station from the power unit or in other cases mentioned in Chapter I check for correct phase sequence of the 220-V line.

16. Do not stand in front of the power unit when it is loaded on or unloaded from the truck. Before letting the power unit down off the truck along the ramps, check whether the winch handle is braked and make sure that the ramp hooks are in their seats.

17. When preparing the antenna pedestal for operation see that its fastening bracket is laid horizontally on the cabin in the travelling position, otherwise the feeder line may be damaged.

18. The supply switch located on the front panel of the automatic air dryer (dehydrator) must always be set in position IN. Switch on or off the dryer by means of switch DEHYDRATOR (W13-6) situated on the control panel.

19. Knob GAIN (R1-44) located on the front panel of the automatic tracking channel amplifier unit must always be set in the extreme right position (maximum gain). When controlling the receiver gain while the station is operating use knob GAIN (R7-39) situated on the front panel of the automatic range finder unit.

Note: Use knob GAIN (R1-44) only when tuning the receiver system as instructed under Part II, Chapter 10.

20. Do not rotate the range handwheel of the range mechanism in the same direction after locking the mechanism in the extreme positions.

.../Chapter I

Chapter I

SELECTION OF SITE, SITING AND PACKING OF STATION

1. SELECTION OF SITE

The selection of an operating site for gun-laying radar SON-9 should meet the tactical and technical requirements for the location of the anti-aircraft battery and is carried out according to the instruction re the combat employment of the gun-laying radar SON-9.

To obtain the maximum target detection range and to minimize errors in determining elevation (height), the operating site should meet the following basic requirements:

- the angle of clearance in the assigned sector or during circular scanning should not be more than 0 - 50;

- nearby transmission or communication lines, high buildings, masts and other similar structures must be avoided around the station at a distance of up to 200 to 300 m.

To position the trailer, flat ground 5x6 m. with an inclination of not more than 10° is necessary.

Besides, land marks (not closer than 2000 m.), suitable for the orientation of the station and battery are necessary. It is desirable that at least one of these landmarks should produce a steady echo signal on the station indicator screens for checking orientation at night and when visibility is poor.

The station should be located not closer than 50 m. from the guns and not greater than 100 m. from the director. The power unit should be placed approximately 50 m. from the station trailer. For supplying purposes the power unit may be set in a trench (a dugout) or may remain on the truck.

The power cable and selsyn drive cable are laid in open channels on spacers.

.../For the

For the purposes of concealment and camouflage the station is placed in a trench. The trench depth should not exceed the height of the radar (up to the cabin roof). Engineering preparation of the site should be carried out according to the "Manual of concealment and camouflage of radar stations".

The typical siting of the SON-9 station on an anti-aircraft battery position is shown in Fig. 240.

2. SITING STATION AND PREPARATION FOR SWITCHING IT ON

Occupying a Position and Siting Station

When occupying a position and siting the station, proceed as follows:

1. Disconnect the lighting cable and the trailer brake hose from the truck and then disengage the truck and the trailer.

Take four wooden pads from the truck body and place them under the trailer jacks.

After the brake hose has been disconnected the trailer is automatically braked. If it is necessary to release brakes allow the compressed air to escape from the air storage tank through the outlet valve. After that shut the cock.

2. Lay the selsyn drive cable to the anti-aircraft fire director and the power cable to the power unit location. Attach the cables to the corresponding connectors of the station external boards and power unit (Figs 202 and 241).

Note: During transportation the cables should be wound on the drums located under the truck body. The right-hand drum carries the selsyn drive and external supply cables.

3. Drive the truck to the place where the power unit is to be unloaded.

4. Using a hand winch lower the power unit to the ground along the ramps which in travelling position are fastened under the trailer body. Then connect the power cable.

.../Note: Before

Note: Before letting down the power unit check whether the winch handle is locked and make sure that the ramp hooks are in their seats. Place a spacer between the ramps.

5. Remove the protective tarpaulin from the cabin top.

6. When operating in winter set and fix the smoke stack which while in travelling position, is secured on the cabin top, open the smoke damper and airfeed vent, and then light the stove.

7. Remove the covers from the main control board, the transmitter and the automatic dryer.

8. Remove the antenna dome and prepare the antenna pedestal for operation.

9. Install the antenna head.

10. Install the echo box antenna and connect it as instructed under Part II, Chapter 10, Section 5.

11. Lower the jacks and level the cabin and the antenna pedestal.

12. Drive the earthing rod in the ground and connect the earthing cable to terminal EARTH on the external board.

13. Open ventilation panes (during operation in summer time).

Preparing the Antenna Pedestal for Operation

To prepare the antenna pedestal for operation, the following should be done:

1. Two members of the station should climb on to the roof of the trailer, stand on both sides of the dome along the division line and release the clasps.

2. Holding the right half of the dome by the horizontal and vertical handles remove it from the antenna and place carefully on the ground. Do the same with the left half.

3. The canvas cover should be removed from the parabolic reflector and optical sight.

4. The fastening upright which holds the paraboloid in the travelling position should be disconnected from it. Put the upright on the roof, otherwise it may damage the feeder line.

5. The reflector should be set vertically by holding it by the frame.

Antenna Head Setting

To set the antenna head, proceed as follows:

1. Unscrew the nut and take one of the two heads out of the holder located on the left-hand wall inside the cabin. Be careful when handling the antenna head not to damage it.

2. Carefully inspect the feeder and polystyrene cap of the antenna head. Check for evidence of dents and burning of the feeder end face and crack on the cap. Check for strength and correct fastening of the clip (the marks on the clip and antenna feeder should be matched). Check for presence of brass and rubber packing rings on the antenna head feeder.

3. Unscrew the protective cap on the end of the head.

4. Insert the antenna head so that the projection on the antenna head feeder clip closely enters the corresponding slot in the reference voltage generator sleeve. Tighten the nut of the antenna head with a wrench holding the sleeve with another one (Fig.242) so that the marks on the nut end face and the antenna feeder are matched.

When setting the antenna head it is essential to use special wrenches kept in the antenna head holder.

Notes: 1. If the antenna head is inserted and fixed incorrectly the automatic tracking system will not operate.

2. To ensure that the protective cap removed from the rotating feeder end is not lost, screw it on the free bushing of the head holder after removal of the antenna head.

.../Levelling of

Levelling of Station

The station should be levelled by the lower levels located on the antenna pedestal base (Fig.243). The readings of these levels should be periodically checked against the reference level located on the antenna pedestal bracket.

Before checking the lower levels verify the reference level. For this purpose set the antenna along the longitudinal axis of the station trailer and by means of jacks get the latter in a position where the air bubble of the level is in the centre of the glass between the reference notches. Then turn the antenna through 180° in azimuth and mark the position of the air bubble. If it remains between the notches the level is set correctly. If the bubble moves in relation to the reference notches the level setting is inaccurate.

For correct setting of the level, half of the value, by which the air bubble is displaced, is taken up by the jacks and the other half by changing the position of the level with the help of the level setting screw. This operation should be done several times until the level bubble, when the antenna is turned 180° from the selected initial position, is between the reference notches.

Having ascertained that the upper reference level is set correctly the station may be levelled against it.

After the antenna pedestal has been levelled by the upper reference level it is necessary to check the position of the lower level and if it is found that the bubbles of these levels are off the glass centres, they should be set in correct position by means of regulating screws.

Then until the position is changed the station may be levelled by the lower reference levels.

Checking the Phase Sequence

The phase sequence should be checked when switching on the station initially after its delivery to a sub-unit, when changing the power unit,

when connecting the station to an external supply, replacing the power cable or after repairing the station, the power unit, or the power cable. Incorrect phase sequence reverses the direction of rotation of all the three-phase motors, which may result in damage to the station.

To check for proper phase sequence of the station, proceed as follows:

1. Start the power unit and apply a voltage of 220 V to the station, setting the voltage value by the voltmeter situated on the power unit board.

2. Switch on the 220-V line by pressing button LINE, 50 c.p.s., on the station control cabinet.

3. Turn on the reference voltage generator switch situated on the control panel for a short period. With the correct phase sequence of the 220-V line the reference voltage generator (M32-7) must rotate clockwise as viewed from behind the reflector. If the direction of rotation is the other way the station phasing should be changed on the power unit, as follows:

- stop the engine of the power unit;
- remove the cap from the feeder panel of the power unit (Fig.241);
- reconnect on terminals 14 and 15 two ends of the cable running through the lower right-hand opening, to the power unit control panel;
- start the engine.

4. Check the phasing of the station once more.

Preparation of Antenna-Feeder System for Operation

After each siting of the radar station and after intervals in its operation exceeding 8 - 10 hours the antenna-feeder system should be blown through. For this purpose proceed as follows:

1. Turn on the main line switch in the control cabinet by pressing button LINE, 50 c.p.s.

2. Switch on the automatic air dryer by placing switch DEHYDRATOR situated on the control panel in position ON (the supply switch on the dryer panel should always be in position ON). Set adjusting knob PRESSURE in

.../a position

a position at which the pressure gauge will read 0.4 kg/sq.cm. Turn knob DEW POINT to its extreme counter-clockwise position. If the cabin air temperature exceeds the normal (+20°C) turn the knob clockwise as far as it will go.

3. Unscrew the cap on the end of the antenna head.

4. Blow out the antenna-feeder system for 5 min. in dry weather and for 10 to 15 min. in cold or damp weather. After that screw the removed caps on the antenna head and the azimuth slow rotating joint again.

These operations are done before switching on H.T. to the transmitter.

5. Switch off the automatic air dryer by placing rotary switch DEHYDRATOR in position OFF.

6. Switch off LINE, 50 c.p.s.

Preparation of Station for Operation in Conjunction with the PUAZO-6

To ensure the operation of the station in conjunction with the PUAZO-6, connect tachogenerator GT-1 to the azimuth drive (the elevation tachogenerator is connected at the Manufacturing plant). In doing this, proceed as follows:

1. Remove the coupling cross-piece after having unscrewed the bolt with a washer securing the coupling to the base.

2. Unscrew two bolts holding the tachogenerator in place and slide it out of the housing by the amount required to fit the coupling cross-piece.

3. Insert the cross-piece projection in the tachogenerator coupling recess aligning them along the diameter.

4. Slide the tachogenerator back into the housing far enough and in such a way that the projection of the coupling fitted on the shaft of the tachogenerator is aligned with the recess of the coupling on the azimuth drive shaft (keep all the washers between the faces). Then fix the tachogenerator in the housing by means of two bolts and clamping lugs.

.../Supply from

Supply from External Power Source

If conditions permit the SON-9 station should be fed from an external power source of three-phase current, 50 c.p.s., with a line voltage of 220 V, which makes it possible to extend the service life of the power unit and to save fuel.

To connect the station to an external power source proceed as follows:

1. Run a special cable to the 220-V external power source.

2. Remove the cover from the power unit feeder board. Pass one end of the supply cable through the lower left-hand opening inside the feeder board and attach it to terminals L1, L2, L3 (Fig.241, a). The other end should be connected to the external power source.

3. Set switch GENERATOR - LINE situated on the feeder board of the power unit to position LINE.

4. Set switch SUPPLY on the power unit control panel in position ON.

5. Check for proper phase sequence, as indicated above.

6. Place the cover of the feeder board in position.

7. Switch on the generator, 427 c.p.s., 110 V.

Further procedure should be carried out as usual.

3. PACKING OF STATION

To put the station in a position to move proceed as follows:

1. Switch off the station, the power unit and stop the engine.

2. Remove the antenna head, screw the protective cap on the outlet of the feeder line and fix the antenna head in the holder inside the cabin.

3. Set the antenna manually in travelling position. Secure the paraboloid by the bracket.

4. Put the canvas covers on the parabolic reflector and the sight.

5. Cover the antenna with two halves of the dome, connect and fasten them and see that the dome halves are set on fixing pins of the ring located on the roof.

.../6. Remove the

6. Remove the echo box antenna and fix it on the main control board. The connector to which the echo box antenna has been attached should be covered with a protective cap. Put the covers on the main control board, transmitter and automatic air dryer.

7. Lift the jacks, fix the handles in travelling position and place the wooden pads on the roof.

8. In winter time remove the smoke stack and place it inside the truck. Close stove openings. Clean the ash pan and shut all the doors and the stove smoke damper.

9. Remove the earthing rod and fix it on the right-hand wall inside the trailer.

10. Prepare the equipment and accessories for the travelling position, check for reliable fastening of the voltmeter, telephone hand sets, chairs, shut the window shutters and cabin doors.

11. Disconnect the cables running to the station, wipe them clean and wind them on the drums mounted under the truck body. After the cables have been wound on, fix the connectors with straps and bolt the drums. The connectors on the cables, external boards of the station and on the power unit should be covered with protective caps.

12. Shut and fix the covers of the station external boards.

13. Cover the trailer roof with a canvas cover.

14. Set the power unit in travelling position.

15. Prepare the truck for loading the power unit. Pull up and secure the unit. The ramps should be placed and secured under the truck body.

16. Hinge the station to the truck and connect the lighting cable and brake hose.

Chapter 2

SWITCHING STATION ON AND OFF

1. CHECKING PRIOR TO SWITCHING ON STATION

After the station has been deployed and before switching it on inspection should be made of the station and setting of switches and control knobs.

Inspection

When inspecting the station, proceed as follows:

1. Make sure that all units of the main control board and transmitter are tightly held in place by screws.

2. Check that there are fuses in the control cabinet, control panel, transmitter and the main control board units.

3. Make sure that the doors of the various transmitter compartments are tightly shut.

4. Make sure, that the antenna pedestal is prepared for operation (See Part II, Chapter 1, Section 2).

Main Settings of Switches and Control Knobs

In all cases, irrespective of whether the station has been operating or is being set up again it is necessary to ensure the correct settings of the switches and control knobs before switching it on.

Check and, if necessary, set knobs FEEDBACK on the azimuth and elevation tracking unit and knob AMPLIFICATION on the automatic tracking unit in the position specified in the station log.

The main settings should be as follows:

O n c o n t r o l c a b i n e t:

Switches MAIN CONTROL BOARD HEATING, VENTILATION placed in position OFF.

Switch LIGHTING placed in position OFF.

O n c o n t r o l p a n e l:

Switches REFERENCE VOLTAGE GENERATOR, AA DIRECTOR, SELSYNS, DEHYDRATOR

.../placed in

placed in position OFF.

Selector switch CONTROL placed in position STATION.

On main control board units:

Switches PLATE and HEATER of the automatic tracking and range channel amplifiers placed in the lower position (OFF).

Switches BRIGHTNESS on the range indicator and range mechanism units placed in the lower position (OFF).

Selector switches CHECK - OPERATION on the range indicator and range mechanism units placed in position OPERATION.

Range tracking switch AUTOMATIC - MANUAL on the range mechanism unit placed in position MANUAL.

Switch on the power pack of the range measuring and plan-position indicator units placed in position OFF; switches "490 V" and "5 kV" in the lower position (OFF).

Automatic tracking unit switch placed in the lower position (OFF).

Knobs BRIGHTNESS and SCALE ILLUMINATION on the plan-position indicator unit turned in the extreme counter-clockwise position.

Knob BRIGHTNESS on the range indicator unit turned in the extreme counter-clockwise position.

Switch INTERLOCKING on the antenna control unit in position OFF.

Selector switch MODE OF OPERATION on the antenna control unit placed in position AUTOMATIC.

Selector switch SCAN SELECTION on the antenna control unit placed in position CIRCULAR.

Selector switch ELEVATION COVERAGE on the antenna control unit placed in position OFF.

Knobs AMPLIFICATION in amplifier units of the automatic tracking channel and automatic range finder placed in extreme right position (maximum amplification).

.../On transmitter

On transmitter cabinet:

The switch on the transmitter control panel in position OFF.

High voltage regulation handwheel LOWER - HIGHER turned to the extreme counter-clockwise position.

Switches HEATER and PLATE on the I.F. preamplifier unit placed in the lower position (OFF).

Selector switch CRYSTAL CURRENTS placed in position SIGNAL, selector switch MANUAL - AFC in position MANUAL.

Instrument switch VOLTAGE CHECK placed in position "-200".

On lighting board:

Selector switch POWER UNIT - STORAGE BATTERY placed in position POWER UNIT.

Four ceiling light switches placed in the lower position (OFF), the table lamp switch in position OFF.

On receiving selsyn unit:

Selector switch GUN-LAYING RADAR-WARNING STATION placed in position GUN-LAYING RADAR.

Switch BRIGHTNESS and selsyn switches placed in the lower position (OFF).

On front panel of automatic air dryer:

- Supply switch placed in position ON.
- Knob PRESSURE turned to the extreme left position.
- Knob DEW POINT turned to the extreme right position.

2. SWITCHING STATION ON AND OFF

The station should be switched on or off in a definite sequence. Failure to observe the prescribed order may cause serious troubles and in some cases, failure of the station. The switching sequence presented in this chapter is fundamental.

.../Switching On

Switching On the Station

To switch on the station, proceed as follows:

1. Start the power unit and supply voltage to the station. The lamps lighting the control cabinet instruments will go on.

2. Set the ceiling light switches on the lighting board in the upper position (ON); the ceiling lights will go on.

3. Turn on the line switches on the control cabinet by pressing buttons ON, LINE, 50 c.p.s. and LINE, 427 c.p.s.

- The voltmeters in the control cabinet should read: VOLTAGE, 50 c.p.s. - 220 V and VOLTAGE, 427 c.p.s. - 110 V. If the voltmeter readings do not correspond to the rated values (220 V, 110 V) it is necessary to send a signal (according to the code table on the control cabinet) to the mechanic by pressing button SIGNAL in order to set normal voltage on the power unit.

- 300 V D.C. will be applied to the field windings of the drive motors located in the antenna pedestal.

- Hum should be heard from the operating fan of the main control board.

4. Switch on the automatic air dryer by setting switch DEHYDRATOR situated on the control panel in position ON. Place knob PRESSURE on the dryer panel in a position at which the pressure gauge will read 0.4 kg/sq.cm. (the cap should be screwed on the antenna head end).

Note: In case of initial switching or intervals in operation exceeding 8 to 10 hours, unscrew the cap from the end of the antenna head and blow out the feeder line with dry air for 5 to 10 minutes. Then install the cap in place.

5. Switch on the transmitter by placing the switch situated on the transmitter control panel in position ON. As a result the motors of the transmitter fans are switched on and pilot lamp MAGNETRON HEATER comes

.../on indicating

on indicating that heater voltage is applied to all the transmitter valves. The instrument lighting lamps on the transmitter control panel will come on as well. The pointer of instrument VOLTAGE CHECK with the selector switch in position -200 should settle between the red notches. In 45 seconds pilot lamp TIME RELAY comes on.

6. Set switch HEATER located on the I.F. preamplifier unit in the upper position (ON), pilot lamp +150 V coming on. Place switch HEATER on the amplifier unit of the automatic tracking channel in the upper position (ON). Set switch HEATER on the range channel amplifier unit in the upper position (ON), pilot lamp -105 V lighting up in some seconds.

7. Place the switch on the power pack of the range measuring and plan-position indicator unit in position ON, the pilot lamp will light up in this case. Further switching on of the unit can follow after 40 seconds.

8. Set the supply switch in the automatic tracking unit in position ON. The pilot lamp comes on and in 10 to 15 seconds the instrument located on the front panel should read 13 - 19 mA.

9. Place switches PLATE on the automatic tracking channel and range channel amplifier units in the upper position (ON). Pilot lamps +120 V and +300 V will come on as a result.

10. Shift switch 490 V on the power pack of the range measuring and plan-position indicator system to the upper position (ON). In this case the unit instrument should read 270 V. The given voltage value is set by STABILIZED VOLTAGE control brought out to the front panel of the unit.

11. Turn knobs BRIGHTNESS on the range indicator unit clockwise; a circular sweep will appear on the screens.

12. Set switch 5 kV located on the power pack of the range measuring and plan-position indicator system to the ON position. If knob BRIGHTNESS is turned a bit to the right the indicator screen displays a radial sweep.

.../13. Set

13. Set switch SELSYNS on the control panel to position ON; the lighting lamps will illuminate the scales of the antenna position indicators in the automatic tracking unit.

14. Switch on the azimuth and elevation amplidynes alternately with a 3 - 4 sec. delay by pressing the corresponding start buttons on the control panels.

15. Set switch INTERLOCKING on the antenna control unit in position ON.

16. Set selector switch MODE OF OPERATION on the antenna control unit to position MANUAL. Check the field currents by instruments FIELD CURRENT located on the panel of the azimuth and elevation tracking unit. The instrument readings should be within 23 to 27 mA.

17. Set the selsyn switches and switch BRIGHTNESS on the receiving selsyn unit in the upper position (ON).

18. Set switches BRIGHTNESS located on the range indicator unit and the range mechanism unit in the upper position (ON).

19. Press button ON, BIAS AND SCREEN on the transmitter control panel, the corresponding pilot lamp will come on as a result. The pointer of instrument VOLTAGE CHECK with the selector switch in positions "+400", "+800" and "-1400" should settle between the red notches on the instrument scale.

20. Press button HIGH VOLTAGE ON, located on the transmitter control panel. In this case:

- the pilot lamp lights up;
- kilovoltmeter HIGH VOLTAGE reads 0 - 2 kV;
- the pointer of instrument VOLTAGE CHECK with the selector switch in position "+4000" settles between the red notches.

21. Set switch PLATE on the I.F. preamplifier unit in the upper position (ON). The pilot lamp +250 V lights up and indicates that rectifier voltage is available. The readings of instrument CRYSTAL CURRENTS should be

.../within 0.2

within 0.2 to 0.6 mA with the instrument switch in position SIGNAL and AFC, which indicates that the oscillator functions normally.

22. Turn high voltage adjustment handwheel LOWER - HIGHER clockwise and bring the voltage to 21 to 23 kV. In this case instrument MAGNETRON CURRENT should read 21 to 23 mA.

23. Shift switch MANUAL, AFC located on the I.F. preamplifier unit to position AFC; a signal produced by the transmitter direct pulse will be displayed on the range indicators.

24. Set the reference voltage generator switch in position ON. In this case the antenna head must rotate clockwise as viewed from behind the reflector.

25a. Check the station supply voltage as measured by the voltmeters on the control cabinet. Voltmeter VOLTAGE 50 c.p.s. should read 220 $\pm$ 3 V. Voltmeter VOLTAGE 427 c.p.s. should read 110 $\pm$ 2.5 V. If the instruments read otherwise bring the voltage to normal having first reduced the high voltage by 2 or 3 kV. Increase the high voltage to 21 - 23 kV again, the magnetron current should be within 21 - 23 mA.

Note: The main control board heater or cabin fan is switched on depending upon the season of the year and temperature conditions. For this purpose set corresponding switches situated on the control cabinet in position ON.

Switching Off the Station

The station should be switched off observing the following sequence of operations:

1. Shift switch INTERLOCKING on the antenna control unit to position OFF. In this case the readings of the instruments on the azimuth and elevation tracking unit will drop to zero.

2. Set selector switch MODE OF OPERATION on the antenna control unit to position AUTOMATIC.

3. Set selector switch SCAN SELECTION on the antenna control unit to position CIRCULAR, if the station before switching off has been operating with sector scanning. Set selector switch ELEVATION COVERAGE on the antenna control unit in position OFF if the station, before switching on, has operated with elevation scanning.

4. Turn high voltage handwheel LOWER - HIGHER on the transmitter control panel toward LOWER as far as it will go.

5. Set selector switch MANUAL - AFC on the I.F. preamplifier unit in position MANUAL.

6. Press button HIGH VOLTAGE, OFF on the transmitter control panel. In this case the pilot lamp goes out, which indicates that the voltage is switched off.

7. Press button OFF, BIAS AND SCREEN on the transmitter control. In this case the pilot lamp goes out, which indicates that the voltage is switched off.

8. Set the switch on the transmitter control panel in position OFF. As a result pilot lamps MAGNETRON HEATER and TIME RELAY will go out and the transmitter fans stop humming.

9. Set switches PLATE and HEATER on the I.F. preamplifier unit in the lower position; the pilot lamps on the unit will go out.

10. Set switches 5 kV, 490 V and the supply switch of the power pack of the range measuring and plan-position indicator unit in position OFF. The pilot lamp will go out.

11. Set the supply switch on the automatic tracking unit in position OFF. The pilot lamp on the unit will go out.

12. Shift selector switch AUTOMATIC - MANUAL on the range mechanism unit to position MANUAL if automatic target tracking in range took place before the station is switched on.

.../13. Shift

13. Shift switches PLATE and HEATER on the amplifier units of the range channel and automatic tracking channel, in succession to the lower position. The pilot lamps on these units will go out.

14. Set switches BRIGHTNESS on the range indicator and range mechanism units in the lower position (OFF).

15. Set knobs INTENSITY on the range and plan-position indicators to the extreme left position.

16. Check to see that switches CHECK - OPERATION on the range mechanism and range indicator units are in position OPERATION.

17. Switch off the azimuth and elevation amplidynes by pressing buttons STOP, AZIMUTH AMPLIDYNE, ELEVATION AMPLIDYNE on the control panel.

18. Set switches DEHYDRATOR, REFERENCE VOLTAGE GENERATOR, SELSYNS, AA DIRECTOR on the control panel in position OFF. The scale lighting lamps of the antenna position indicators will go out and the air dryer will stop operating.

19. Set switches VENTILATION and MAIN CONTROL BOARD HEATING on the control cabinet in position OFF.

20. Press button OFF, LINE, 50 c.p.s., and LINE, 427 c.p.s., on the control cabinet. In this case the main control board fan will stop humming.

21. Send a signal to the mechanic to turn off the power unit.

Chapter 3

CHECKING THE OPERATION OF UNITS AND ADJUSTMENTS REQUIRED

The present chapter outlines checks and adjustments of the unit that are carried out after the radar station has been set up, during daily inspection, repair and, if time permits, before combat operation. Checking is carried out to make sure that the station and units are fully serviceable.

The operators may perform only those adjustments that are specified below. If the checking reveals that the units operate abnormally and they cannot be rendered serviceable by the adjustments listed in the present chapter perform the adjustments described in Part II, Chapter 10.

The operation of the units when the station is switched on should be checked in the following sequence.

1. CHECKING THE OPERATION OF ANTENNA POSITIONING SYSTEM

1. Check the position of knobs AMPLIFICATION (R6-9) and FEEDBACK (R10-24 and R10-74). These knobs located on the front panels of the automatic tracking - and azimuth and elevation tracking units must be kept in positions stipulated in the station log book.

2. Check the readings of instruments FIELD CURRENT. When checking set the instrument selector switch (W10-1) located on the azimuth and elevation tracking unit alternately in positions AZIMUTH and ELEVATION. The instrument reading should be equal to 25 ± 2mA.

3. Check the action of feedback. Turn the azimuth handwheel on the antenna control unit. The antenna should rotate in azimuth and take up a new position making not more than four oscillations about the new position. Turn the elevation handwheel. The antenna should be tilted in elevation and take up a new position making not more than four oscillation cycles (watch the azimuth and elevation fine scales located on the receiving selsyn unit).

4. Check the working of the system during circular and selector scanning. Shift selector switch MODE OF OPERATION (W12-1) situated on the antenna control unit to position SCANNING and selector switch SCAN SELECTION to position CIRCULAR. Set selector switch ELEVATION COVERAGE to position ON. In this case the antenna should rotate clockwise in azimuth (as viewed from above) at a speed of 9 to 13 r.p.m. and oscillate in elevation in a sector from 1 - 70 to 2 - 10. The azimuth scales must rotate clockwise evenly without jerks.

After that set selector switch SCAN SELECTION to position SECTOR. The antenna should swing in azimuth in a sector from 4-00 to 9-00 at a rate of 26 to 34 cycles per minute and in elevation in a sector from 1 - 70 to 2 - 10. The antenna should be lifted for four oscillation cycles in azimuth and lowered for one cycle.

5. Check the operation of limit switches and the electric braking system. Rotate the elevation handwheel on the antenna control unit clockwise; this causes lifting of the antenna and simultaneous clockwise rotation of the coarse elevation scale in the automatic tracking unit and the fine azimuth scale in the receiving selsyn unit. When the antenna reaches the upper position the upper limit switch and the electric braking relay should operate, thus causing the antenna to stop.

The reversal of the elevation handwheel direction of rotation should cause the antenna to move down and the scales of the coarse and fine elevation selsyns to rotate counter-clockwise. When the antenna reaches the lower position the lower limit switch and electric braking relay should operate, thus causing the antenna to stop.

When the antenna assumes the upper or lower positions the elevation amplidyne should not be overloaded (it should not produce a peculiar noise-howl).

Note: As soon as the antenna moves from the upper or lower extreme positions, repeated clicks of the electric braking relay accommodated in the antenna pedestal may be heard.

.../6.

6. Check balancing of the D.C. amplifiers of the azimuth and elevation tracking unit. Turn knob AMPLIFICATION (R6-8) on the automatic tracking unit to its extreme counter-clockwise position. Set the antenna by the elevation handwheel through an angle of about 7-00. Make sure that the reference voltage generator is energised. Shift selector switch MODE OF OPERATION (W12-1) on the antenna control unit to position AUTOMATIC and watch the antenna position scales (fine and coarse) located on the receiving selsyn unit.

If the D.C. amplifiers of the azimuth and elevation channel are balanced the antenna will remain still. If the antenna starts to rotate it should be stopped, i.e. balance the D.C. amplifiers by turning the shaft of the appropriate potentiometer BALANCE (R10-12 or R10-62) located on the azimuth and elevation tracking unit in the counter rotational direction of the corresponding scales.

7. Check the operation of the follow-up motors. Rotate the antenna control handwheels five turns (with selector switch MODE OF OPERATION in position AUTOMATIC) and notice the azimuth and elevation scale readings. Then shift the selector switch to position MANUAL. The antenna displacement in azimuth and elevation should not be greater than 1-25.

2. CHECKING THE OPERATION OF THE RANGE MEASURING SYSTEM

Before checking, shift selector switch OPERATION - CHECK (W3-1) on the range indicator unit to position CHECK. While checking, proceed as follows:

1. Check definition and brightness of the sweep on the screens of the range indicators. If the sweep trace is blurred, focus the electron beam and set normal brightness by knobs FOCUS (R3-16 and R3-17) and INTENSITY (R3-13 and R3-14) on the range and very narrow gate indicator unit.

The fine range indicator should display two clear markers on the sweep trace in the form of two dark spots making the fine range electronic marker. The coarse range tube sweep should have a marker in the form of

.../a high

a high lighted sweep section making the coarse range tube electronic marker.

The range operator should choose suitable brightness of the sweep so as not to overstrain his eyes during manual range tracking. At the same time the sweep should not be too bright for this shortens the life of the indicator tubes.

2. Check the form of the sweeps on the screens of the range indicators and their position relative to the reference circles. By turning knob STROBE WIDTH (R8-88) of the range unit, set the strobe width of the fine range tube sweep by the range scale, the width being equal to 2 km.

The sweeps should have the form of circles concentric in relation to the reference circles, (engraved on the discs in front of the tube screen and having 55 mm in diameter). The circular sweep diameter must be 50 mm.

When tuning a sweep make sure that the sweep coincides with the reference circle by turning in succession knobs CENTRING (R3-26, R3-27 and R3-31, R3-32) on the range indicator units, DIAMETER (R8-36, R8-21), PHASE (C8-58, C8-65) and BALANCE (R8-18, R8-19) on the range unit.

Note: When tuning the fine range sweep, use knobs marked SWEEP 2 km. and the coarse range sweep, knobs marked SWEEP, 40 km.

Then by operating knob DIAMETER (R8-36, R8-21) set the sweep diameter equal to about 50 mm. Accurately align the sweep with the reference circle prior to checking and regulating the linearity of the fine range electronic marker, for this accounts for the accuracy of the electronic marker checking and regulation, which in turn determines the magnitude of periodic errors in range measurement.

During the operation of the station thoroughly check and adjust the range sweeps, since the sweep distortions lead to errors in range measurement.

3. Check linearity of the fine range electronic marker. Linearity should be checked by the carefully adjusted sweep of the fine range tube.

Check linearity within 2 km. every 100 m. of the range mechanism fine scale, for which purpose proceed as follows:

.../- turn the

- turn the rotary reference disc in front of the fine range indicator so that its radial index notch comes to rest against zero division of the indicator scale (the remaining disc notches in this case are set at values 5, 10 and 15);

- by operating the manual range tracking handwheel of the range mechanism match the end of the first spot of the electronic marker in succession with the four notches of the reference disc, noting the readings of the range mechanism fine scale.

The same operations should be done when setting the reference disc notches to divisions 1, 2, 3 and 4 of the fine range indicator scale.

Note the measurement results in sequence.

Linearity of the electronic marker is considered normal if twenty measurements taken off the fine scale of the range mechanism differ one from another by a value not exceeding $\pm$ 20 m., i.e. the maximum variation in readings is not greater than 40 m. In this case the differences in measurements divisible by 100 m. are negligible.

4. Check setting of range zero indication. Inaccuracy in setting range zero indication causes a systematic error in range measurements.

Before checking allow the completely energised station to warm up for at least 20 min.

Set selector switch OPERATION - CHECK (W3-1) on the panel of the range indicator unit to position OPERATION. By rotating the range handwheel set the end of the first spot of the fine range electronic marker against the beginning of the trigger pulse leading edge. Take the readings on the range mechanism scales and compare them with the value given in the log book of the Station. If the scale indications differ from the data specified in the log book by more than $\pm$ 10 m. turn the shaft (ZERO SETTING) coupled with the phase shifter stator (on the panel of the range mechanism unit) to obtain the required scale readings.

.../5.

5. Check strobe pulse sequence linearity. Operate knob STROBE WIDTH (R8-88) of the range unit and set by the scale the strobe pulse width on the sweep of the fine range indicator equal to 1 km. Turn the range handwheel and zero the range scale. In this case the strobe pulse on the sweep of the fire range indicator must be located approximately in symmetry with the electronic marker; the transmitter direct pulse should be observed on the sweep.

If this condition is not fulfilled, operate knob STROBE CONTROL - BEGINNING (R4-23) located on the front panel of the range mechanism unit and arrange the strobe as instructed above.

Slowly rotate the mechanism scales by the range handwheel to 40 km. (on the scale). The strobe pulse should not come off the electronic marker. The strobe pulse position can be adjusted by rotating the shaft of potentiometer STROBE CONTROL - END (R4-25). After adjusting the shaft of potentiometer END check the strobe pulse position again with the mechanism scales at zero, and further with the scales rotating towards 40 km, making, if necessary, adjustments by potentiometers BEGINNING (R4-23) and END (R4-25).

The strobe pulse sequence linearity is considered normal if, when rotating the mechanism in both directions within 0 and 40 km., the strobe pulse corresponding to 1 km. does not come off the electronic marker.

6. Check gating of the coarse range indicator sweep. The sweep should be gated along the whole circumference. A small gap should remain between the ends of the gated part.

The necessary adjustment of gating width is made by the shaft potentiometer GATING WIDTH (R8-77) of the range unit.

7. Check balancing of the automatic range finder. (This and the following items are carried out after checking the receiving and the antenna positioning systems).

By operating elevation handwheeel tilt up the antenna through such an

.../angle

angle that the screens of the range tubes do not display the ground clutter. Operate knob AMPLIFICATION (R7-99) on the automatic range finder unit to obtain such amplification of the receiver that the noise amplitude on the range indicator is about 2 mm.

Set the mechanism scale to 20 km. division using the range handwheel.

When setting switch MANUAL - AUTOMATIC (W4-4) situated on the range mechanism unit to position AUTOMATIC, the scales of the range mechanism should not rotate. If the scales rotate, balance the range finder; for this purpose:

- cut out the receiver amplification by turning knob AMPLIFICATION (R7-99) on the automatic range finder unit to its extreme counter-clockwise position;

- set the shafts of potentiometers BALANCE-1 (R7-93) and BALANCE-2 (R7-80) of the automatic range finder unit in the middle position;

- turn the shaft of potentiometer BALANCE-3 (R7-17) until the scales come to a stop.

Set the noise level to about 2 mm and operate potentiometer BALANCE-1 (R7-93) and BALANCE-2 (R7-80); balance the system, i.e. stop the whole mechanism or get it to swing slightly in either direction.

If the system is difficult to balance in the described sequence set potentiometers BALANCE-1 (R7-93) and BALANCE-2 (R7-80) in the middle position and with the given noise level obtain coarse balancing of the system by potentiometer BALANCE-3 (R7-17). Then operate knobs BALANCE-1 (R7-93) and BALANCE-2 (R7-80) to obtain the best balancing of the system.

After checking under the present item shift switch MANUAL - AUTOMATIC (W4-4) of the range mechanism unit to position MANUAL.

8. Check the operation of the automatic range and landmark tracking system. Operate the elevation and azimuth handwheels to aim the antenna at a clearly visible landmark. Adjust the receiver amplification by knob AMPLIFICATION (R7-99) located on the automatic range finder unit so that the

echo signal on the indicators is not limited.

Set the range handwheel to the tracking position (away from you) and align the end of the fine range electronic marker with the beginning of the echo signal.

Shift switch MANUAL – AUTOMATIC (W4-4) of the range mechanism unit to position AUTOMATIC. The marker should, after two or three oscillations, settle in symmetry with the echo signal.

Set switch MANUAL – AUTOMATIC (W4-4) to position MANUAL.

Match the beginning of the electronic marker with the end of the echo signal and shift the switch to position AUTOMATIC. After two or three oscillations the marker must settle in symmetry with the echo pulse.

If the electronic marker settles sluggishly to the signal or if, vice versa, after setting to the signal, it goes on oscillating, adjust amplification of the automatic range tracking system by turning knob AMPLIFICATION (R7-56) of the automatic range finder unit.

3. CHECKING THE OPERATION OF THE PLAN-POSITION INDICATOR SYSTEM

1. Check the shape of sweep on the screen of the plan-position indicator. Put the receiver amplification at zero by turning knob AMPLIFICATION (R7-99) of the automatic range finder unit to its extreme counter-clockwise position. Turn knob INTENSITY (R11-35) on the plan-position indicator unit clockwise so that the sweep trace becomes visible on the indicator. Operate knob FOCUS (R11-50) to obtain a clear sweep trace.

Set selector switch MODE OF OPERATION (W12-1) situated on the antenna control unit to position SCANNING, and selector switch SCAN SELCTION to position CIRCULAR. In this case the sweep should rotate (clockwise) in synchronism with the antenna. The rotations must be smooth and the sweep not distorted. The length of the sweep trace should be approximately equal to the screen radius and display six range markers. The space between the range markers should be equal.

Readings of the antenna azimuth indicator of the range finder unit should coincide with those on the P.P.I. scale.

Check and, if necessary, set normal brightness of the concentric circles formed by range markers and the strobe pulse using knobs STROBE BRIGHTNESS (R11-47) and MARKER BRIGHTNESS (R11-29) of the plan-position indicator unit. They should be brighter than the sweep and darker than the target echoes.

2. Check indication of the targets on the plan-position indicator unit. Set selector switch MODE OF OPERATION (W12-1) on the antenna control unit to position MANUAL.

Turn knobs AMPLIFICATION on the amplifier unit of the automatic tracking channel (R1-44) and the automatic range finder (R7-99) clockwise as far as they will go. Set the antenna to approximately zero elevation using the elevation handwheel. In this case the screen of the plan-position indicator should display background return, which testifies to the signal being furnished from the receiver.

3. Check for correct setting of range markers. Operate the range handwheel and set the range mechanism scales to 20 km. Use knob STROBE WIDTH (R8-88) located on the range unit to set the width of the strobe pulse on the fine range indicator equal to 300 m. as measured on the scale.

On the plan-position indicator screen the strobe marker should coincide with the second range marker.

After checking set (on the scale) the width of the strobe pulse of the fine range tube equal to 1000 to 1500 m.

4. CHECKING THE TRANSMITTER

1. Check the driver voltages. In doing this shift the knob of selector switch "+400 +800 -200 -1400 +4000" (W25-4) to all the five positions in succession, the pointer of instrument VOLTAGE must settle between the red notches.

2. Check voltage by instrument HIGH VOLTAGE which should read 21 to 23 kV. With some other readings of the instrument bring the voltage to normal by rotating handwheel LOWER - HIGHER; the readings of instrument MAGNETRON CURRENT in this case should not exceed 20 to 23 mA.

5. CHECKING THE STATION OPERATION BY ECHO BOX

1. Check the operation of the radio-frequency part of the station. This procedure is carried out with the help of an echo box as instructed under Part II, Chapter 10, Section 5.

2. View the presentation of "local objects" on the range and plan-position indicators. In this case pay special attention to the magnitude of the signals returned from distant objects.

<u>Note</u>: When observing the "map-like presentation of local objects" bear in mind that it may be changed not only due to abnormal operation of the station but also due to variation of weather conditions and time of the day.

6. CHECKING THE OPERATION OF AUTOMATIC TRACKING SYSTEM

The automatic tracking system operation may be checked by separately located landmarks producing steady echo pulses. Such landmarks may be factory chimneys, towers, beacons and specially constructed "ground features" as a pole, a tower, on which a metal reflector is mounted (tin sheet, gauze, "brush", etc.).

When checking proceed as follows:

1. Point the antenna to the landmark by means of the azimuth and elevation handwheels.

2. Set the electronic marker in symmetry with the echo pulse.

3. Shift selector switch MODE OF OPERATION (W12-1) located on the antenna control unit to position AUTOMATIC. The antenna should automatically get aimed at the landmark. In this case the current indicated by the instrument located on the front panel of the automatic tracking unit, will drop to 7 - 6 mA, which is evidence of the correct

selection of the operating point on the error amplifier valve characteristic. The noise level on the screen of the coarse range indicator should decrease, which testifies the normal operation of the receiver automatic gain control system. On pressing the ERROR SIGNAL - OFF, button (W4-5) on the main panel of the range mechanism unit, the current should drop to zero.

4. Find the true azimuth and elevation of the landmark on the scales of the receiving selsyns.

5. Shift selector switch MODE OF OPERATION (W12-1) to position MANUAL.

6. Rotate the antenna by 0-50 in relation to the target direction by aid of the azimuth and elevation handwheels.

7. Shift selector switch MODE OF OPERATION (W12-1) to position AUTOMATIC. The antenna should settle pointing to the landmark making not more than three oscillations.

The difference between the receiving selsyns' indications should not exceed 0-10.

/Field comment: This remark seems to be out of place here, and some of the text is probably missing/

Chapter 4

ORIENTATION OF RADAR STATION

1. GENERAL

The station should be oriented each time after it has been set up on the position.

Prior to orienting the station check and adjust the station units as instructed under Part 2, Chapter 3; check levelling of the antenna pedestal (Part 2, Chapter 1) and alignment of the sight optical axis and antenna electrical axis and alignment of the station in elevation.

After the station has been oriented, orient the anti-aircraft fire director and anti-aircraft guns of the battery and match the synchro drives. These activities are described in "Instructions for the employment of Gun-Laying Radar SON-9".

At night and in the absence of a visible aiming point the radar station and the anti-aircraft fire director are oriented by mutually sighting the station and the anti-aircraft fire director. For this purpose a special lamp is installed beside the sight, the lamp being covered with a cap, which is screwed off during sighting. The lamp is fed through a special cable via connector Zw32-1.

2. CHECKING FOR ALIGNMENT OF SIGHT OPTICAL AXIS AND ANTENNA ELECTRICAL AXIS

The antenna electrical axis is an imaginary line connecting the antenna of the station with the target that is automatically tracked when the error signal returned from the target equals zero.

The antenna electrical axis approximately coincides with the dipole rotation axis and is set at right angles to the pedestal elevation rotation axis at the Manufacturing plant.

The sight optical axis is an imaginary line connecting the centre of the sight object glass (Fig. 244) with the distant point seen in the centre of the sight crosshairs. To ensure fine readings of the coordinates

parallel since the checking in elevation and orientation of the radar station in azimuth are carried out with the help of the sight.

Used as an air target for checking is an aircraft flying so that its angular coordinates change as slowly as possible or a pilot balloon with a suspended angle reflector (tinfoil pasted on cardboard).

During automatic target tracking it should be located in the sight field of vision (Fig. 245) and oscillate about the centre of the crosshairs remaining as a rule within limits of circle 0-02. It is assumed that the station operates normally and all the required adjustments and tuning are made beforehand. Occasional deviations are allowed.

3. CHECKING THE STATION IN ELEVATION

To check the station in elevation, proceed as follows:

1. Check and, if necessary, adjust the levelling of the antenna pedestal.

2. Take the reflector frame by the hands and aim the antenna at any landmark (the apex elevation of which is determined beforehand topographically or with any protractor) so that the horizontal line of the sight crosshairs coincides with the landmark apex.

3. Turn on master line switch LINE, 50 c.p.s. (W31-1) located on the control cabinet if the station is not energised and shift switch SELSYNS (W13-4) to position ON.

4. If the station is energised shift switch INTERLOCKING situated on the antenna control unit to position OFF and switch off the azimuth and elevation amplidynes.

5. Set switch GUN-LAYING RADAR - WARNING STATION (W44-1) on the receiving selsyn unit to position WARNING STATION.

6. Switch on the brightening and fine elevation selsyn on the receiving selsyn unit.

7. Check the readings of elevation on the coarse scale located on the automatic tracking unit and on the fine scale of the receiving selsyn unit.

Should necessity arise set the required value of elevation by turning the scales. For this purpose remove the framing of the corresponding scale and loosen the screws holding the scale and after adjusting fasten the scale and place the framing in position.

The station may be checked in elevation by mutually sighting the station antenna with a gun thoroughly checked (by the gunner's quadrant), the gun being 100 to 300 m. from the station. The centre line of the gun should be aimed at the station sight through the firing pin holes and the muzzle brake crosshairs. As with checking the station by a landmark elevation is read on station selsyn scales. The elevation must equal the elevation read on the gun scales but opposite in sign. If the elevation data do not coincide make adjustments as instructed above under point 7.

4. ORIENTATION IN AZIMUTH

To orient the station in azimuth it is necessary to have an aiming point located not less than 2 km. from the station.

When orienting in azimuth, proceed as follows:

1. Remove both halves of the antenna pedestal dome.

2. Turn on master line switch LINE, 50 c.p.s. (W31-1) on the control cabinet (if the station is not switched on).

3. If the station is energised, shift switch INTERLOCKING on the antenna control unit to position OFF and switch off the azimuth and elevation amplidynes.

4. Switch on the scale brightening of the fine azimuth transmitting selsyn.

5. Climb on the roof and take the reflector frame by the hands and rotate the antenna in azimuth, simultaneously observing the optical sight, until the sight vertical line coincides with the landmark being used to orientate the station.

6. Release the selsyn drive, for which purpose pull the handle of the

locking mechanism as far to the left as it will go. The mechanism is located on the main gear of the azimuth motor drive.

7. Turn the handle of the antenna pedestal azimuth selsyn drive to adjust the scale of the fine azimuth transmitting selsyn to zero or reference reading, checking the setting accuracy by the azimuth scales of the antenna position indicators and the receiving selsyn unit.

8. Secure the selsyn drive by pushing the handle of the locking mechanism as far as it will go to the right.

9. Switch on the power pack of the range and plan-position indicator system. Check the position of the sweep trace on the P.P.I. screen. If it is not aligned with the azimuth indicator position in the automatic tracking unit, then (by turning the stator of the P.P.I. system transmitting selsyn), move it to the correct position on the indicator screen.

10. Place both halves of the antenna pedestal dome in position and fasten them.

11. Switch off the station if it is not to be used for combat operation.

Chapter 5

COMBAT OPERATION

The following chapter is concerned with the general principles of the operation during scanning and tracking of an air target. Detailed directions for duties of each member of the station personnel are given in the "Instructions for Anti-aircraft Artillery using the Artillery Radar Station SON-9".

1. SCANNING AND TRACKING

When operating the station, two types of scanning are employed:

(1) scanning according to target indications, which is divided into azimuth and range scanning and square scanning;

(2) scanning without target indications which is divided into automatic circular, automatic sector and manual scanning.

Scanning according to target indications can be used when the station operates in conjunction with a warning station. In this case the coarse range and azimuth data of the given target is furnished to the SON-9 station from the warning station. In the given case the indicators of the receiving selsyn unit serve as azimuth and range coarse indicators, switch GUN-LAYING RADAR - WARNING STATION being in position WARNING STATION.

During scanning by target indications when the location of the target is approximately known the antenna is set in the assigned azimuth with due allowance for lead after which it is turned in azimuth in either direction by 2-00 to 3-00 and tilted up and down in elevation depending upon the direction of the target movement (opposite scanning).

For square scanning the screen of the plan-position indicator is fitted with a transparent overlay with an artillery grid plotted on it, the overlay being held on the screen by means of a special holder. In this case match the range markers of the P.P.I. sweep with the grid scale by turning the shaft of potentiometer SWEEP LENGTH on the plan-position indicator unit.

Automatic circular scanning is used only in those cases when there is no information on the target location. For changing over to the given mode of operation shift selector switch MODE OF OPERATION on the antenna control

unit to position SCANNING; selector switch SCAN SELECTION, to position CIRCULAR; and selector switch ELEVATION COVERAGE to position ON. In this case the antenna is automatically rotated in azimuth and is tilted up and down in elevation within a sector of about 2-00. The initial position of the antenna in elevation is set by the handwheel so that the expected elevation is within the limits of elevation scanning. Sector scanning is resorted to in case the target coordinates are approximately known or the station is intended for operation in a predetermined sector.

Automatic sector scanning is switched on by setting selector switch MODE OF OPERATION to position SCANNING, selector switch SCAN SELECTION to position SECTOR. In this case the antenna oscillates in azimuth in a sector about 7-00. Simultaneously a sector of about 2-00 is scanned in elevation.

During all modes of operation the operators observe the display of the target echo on the station indicator screens. The target echo is displayed in the form of an echo-arc. The target echo is presented as a narrow pulse on the coarse range indicator and as a wide pulse on the fine range indicator (Fig. 246). The target azimuth is read on the P.P.I. scale against the middle of the echo-arc. The target range is read off the range markers on the screen of the plan-position indicator. It may also be read on the scales of the range mechanism, for which purpose it is necessary to match the strobe pulse with the target echo on the plan-position indicator by turning the range handwheel.

The target squares are determined by the artillery grid. The direction of the target flight may be determined by the target echo movement on the screen of the plan-position indicator.

When scanning in low elevation the screen of the plan position indicator displays aircraft targets and near-by objects. These echoes remain stable , immovable and disappear or decrease in intensity when the antenna is lifted through a certain angle. The operators should be well aware of the location and presentation of the near-by objects so as not to confuse them with the target echoes.

After a target has been detected the next stage, called tracking, follows. The operators continuously follow the target by turning the azimuth and elevation handwheels and determine its range.

2. TARGET TRACKING

Automatic tracking is resorted to when the aircraft is less than 40 km. from the station. The electronic marker of the coarse range tube is matched with the signal returned from the selected target by means of the range handwheel. The target echo in this case appears on the sweep of the fine range tube.

When tracking the target in range the electronic markers of the fine range tube are matched with the signal returned from the target, i.e. the signal is placed in symmetry between the dark spots of the electronic marker.

When the electronic markers of the fine range tube are matched with the target echo, selector switch MODE OF OPERATION should be set in position AUTOMATIC, after which the antenna follows the target automatically in azimuth and elevation.

The range electronic marker is continuously matched with the target echo on the screens of the range indicators by a handwheel (in this case the handwheel should be pushed forward).

For changing over to automatic tracking in range, shift selector switch MANUAL - AUTOMATIC situated on the range mechanism unit to position AUTOMATIC. After that the station will track the target in range automatically.

If a signal returned from another target appears between the spots of the electronic marker the station may spontaneously start tracking the new target or else the antenna will oscillate. To avoid this, the range operator must change over to manual tracking of the target in range and watch the two target echoes approaching on the sweep of the fine range indicator. At the instant the signal returned from the interfering target approaches the electronic marker it is necessary to push button ERROR SIGNAL OFF on the range mechanism unit and keep it pressed for not more than 3 sec. In this case the automatic target tracking system is switched off and the antenna moves

under its own momentum. The button being released, make sure that the station goes on tracking the selected target (the target echoes on the range - and plan-position indicators must move in the former direction).

When the target is missed place selector switch MODE OF OPERATION in position MANUAL and search for the target with the aid of the azimuth and elevation handwheels.

3. REMOTE CONTROL FROM THE PUAZO-6

The station is provided for remote control from the PUAZO-6. This method is used when targets are distinctly seen through the optical sights of the PUAZO-6.

For changing over to remote control from the anti-aircraft fire director set selector switch CONTROL located on the control panel to position AA DIRECTOR and selector switch MODE OF OPERATION situated on the front panel of the antenna control mechanism unit to position MANUAL.

The target is tracked according to angular coordinates with the help of anti-aircraft fire director optical sights. In this case the antenna of the station moves in azimuth and elevation in synchronism with the anti-aircraft fire director.

In the given mode of operation the range operator ensures target tracking in range while the target range data are used in the PUAZO-6.

Should the necessity arise of going over quickly to automatic target tracking according to angular coordinates shift selector switch MODE OF OPERATION to position AUTOMATIC and selector switch CONTROL to position STATION.

4. OPERATION PECULIARITIES UNDER RADAR INTERFERENCE

The operators must be prepared beforehand for operation under conditions when the enemy uses radar interference. Strong interference may paralyse the radar operation for a while but under no circumstances should the station be switched off lest the enemy should become aware of the effectiveness of the interference.

It will be necessary to resort to manual tracking in range and take

measures to continue target observation and tracking.

Radar interference may be classified as active (jamming transmitters) and passive (angle reflectors, window, etc.)

Active Interference

Depending upon the type of radiation of a jamming transmitter (continuous, pulse, etc.) returns displayed on the indicators screens will vary. Interference causes overloading of the receiver and decrease of the target echo amplitude on account of the action of the automatic gain control. With weak interference the target echo can be seen against the interference background. With strong interference the signal fades away which renders automatic target tracking impossible. In this case it is necessary to resort to manual tracking, decrease the receiver amplification by knob AMPLIFICATION located on the amplifier unit of the automatic tracking channel and then to track the target manually, if possible, by maximum signal amplitude on the coarse range tube.

Due to narrow radiation pattern of the antenna the interference from the jamming transmitter affects adversely only a small sector. When the target comes out of this sector it may be tracked as usual. Therefore, care should be taken not to miss the target in the jamming sector and to follow it continuously.

It is essential to quickly determine the direction of the source and nature of interference. The azimuth and elevation data of the jamming transmitter may be determined by finding the antenna position at which the effect of interference is at maximum.

Passive Interference

Window, whose length equals or is greater than the half of the station wavelength, intensively reflect radio waves and create pulses like signals returned from targets. The pulses differ from target echoes in that they move along the sweep slowly and fluctuate.

With a great amount of window in the air automatic target tracking is made impossible. However, the target echo may be distinguished from

fluctuating pulses, which permits the target to be kept in view during manual control of the antenna and to change over to automatic tracking immediately after the target has left the interference zone.

When tracking an aircraft dropping window, the moment of separation can be distinctly seen on the screen of the fine range indicator. The target echo widens and separates from the edge of a new signal.

As a result of interference, the station may miss the target and start tracking window. To avoid this, the operator should push button ERROR SIGNAL OFF at the right time.

In case of heavy interference it is necessary to resort to manual control of the antenna, decrease the receiver amplification and watch the target according to the maximum pulse.

.../Chapter 6

Chapter 6

TRANSPORTATION OF RADAR STATION

1. TRANSPORTATION BY TRUCK

To prepare the station for the travelling position, proceed as follows:

1. Pack up the station according to the instructions given in Part 2, Chapter 1, Section 3.
2. Check for fastening of the main control board units, the transmitter cabinet units, the echo box and its antenna, operator's chairs, service equipments, the main control board casing, the transmitter cabinet, the antenna pedestal, the amplidyne cabinet and other equipment.
3. Check the packing and fastening in the truck of the power unit, spare parts cases, entrenching tools, accessories for unloading the power unit, cable reels, the tarpaulin cover and other equipment. In winter time check to see that water is drained off the power unit engine radiator.
4. Drive the truck to the trailer, engage the towbar with the truck hook, connect the lighting cable and the trailer brake hose to the truck.
5. Check the operation of the rear stop lights and the trailer brakes when braking the truck. Check the pressure in the truck-trailer brake system as measured by the pressure gauge located in the truck cabin. If the pressure is lower than 4.5 kg/sq.cm. raise it when the truck engine runs at no-load.
6. Check for reliable coupling of the truck and trailer, for which purpose drive the truck a bit forward.

When transporting the station care should be taken to avoid jerks and knocks which may cause damage to the equipment.

The transportation speed on main roads should not exceed 40 km/hr, on soil and cobblestone roads 25 km/hr and when driving over cross-country or rough terrain 5 km/hr.

During transportation check periodically every 30 to 50 km the state

of :-

- the coupling of the trailer with the truck and the trailer towbar and turning gear components;
- the fastening of the trailer wheels;
- the chassis
- the truck-trailer brake system.

Check the packing and fastening of the equipment inside the trailer and truck every 200 km. and every 100 km. in case of rough terrain.

Should the necessity arise to move the trailer backward, proceed as follows:

- drive the truck forward until the truck is lined up with the trailer;
- remove towbar lock 7 (Fig.226) from holder 8 and swing it through the openings of the bracket and towbar as indicated by a dash-and-dot line on Fig.226. In this case the front trailer wheels cannot be turned;
- move the trailer backward slowly without jerks as far as it is required;
- then remove lock 7 out of the openings in the bracket and towbar and install it in holder 8; in this case the front wheels and the towbar can be freely turned.

Note: Backward movement of the trailer, when the truck is misaligned with the trailer by more than 8 to 10 degrees, is not recommended.

2. TRANSPORTATION BY RAILWAY

Before loading for transportation by railway the station and the truck should be in the travelling position.

To fix them on a flat prepare the following:-

- wooden blocks, 100 x 150 x 2750 mm, nine per set;
- wooden blocks, 100 x 150 x 530 mm, ten per set;
- 6 mm soft annealed wire, about 100 m;
- cramp irons, 50 per set;
- boards of not less than 40 mm for making loading ramps and spanning platform between the flats if the train is loaded with several

The station should be transported on 50- or 60-ton railway flats.

Preparing the Loading Area

To prepare the loading area, the following should be done:

1. A 50- or 60-ton flat should be placed sideways or end-on to the platform with the flat side gates open beforehand.

2. The flat should be braked with brake shoes or by the locomotive.

3. Spanning platforms should be placed between the end or side platform and flats and between the flats.

Note: A brake van, if any in the train, must be put at the end during loading.

Loading the Trailer and Truck onto a Flat

The loading procedure is as follows:

1. The trailer is placed on the flat by means of the truck. The direction of the truck movement should ensure symmetrical installation of the trailer and truck relative to the longitudinal and lateral axes of the flat (Fig.247).

After the station has been installed on the flat the truck and trailer must be braked. The trailer towbar should be put under the truck rear wheel and fastened to the floor of the car by cramp irons.

After loading the station proceed as follows:

- drain fuel from the tank and water from the truck radiator;
- close the shutters of the truck engine radiator;
- shift into first gear;
- shut the windows and doors of the truck cabin.

2. Fasten the trailer with four wooden blocks (100 x 150 x 2750 mm) across and with four blocks on the sides of the tyres along the flat. To make support more effective the block edge that faces the wheel should be cut and shaped to the wheel.

Fix the blocks to the flat with cramp irons, four required per one side of the lateral block and two per two sides of the longitudinal block.

3. Fasten the trailer with four stays of 6 mm soft annealed wire (each

stay made of four twisted wires). One stay end is fastened to the wheel hub, the other to the bracket or eye-bolt of the flat.

4. Fasten the truck with five wooden blocks (100 x 150 x 2750 mm) across and with six blocks on the sides of the tyres along the flat. Secure the blocks on the flat and interconnect them with cramp irons.

5. Fasten the truck with four stays (stay made of four twisted wires). One stay end should be attached to the axle at the wheel, the other to the bracket or eye-bolt of the flat. See that the stays do not brush against the wheel tyres.

6. Remove spanning platforms and ramps, shut the side gates of the flat and fix them with wire.

Caution: When the station is being transported by rail it is forbidden to marshal the train in hump-backed yards, to brake the engine fiercely or knock the flat.

Chapter 7

CARE AND MAINTENANCE

1. GENERAL

The technical condition of the station depends upon proper operation, timely inspection, cleaning, lubrication of the equipment and putting right any faults which arise.

To keep the station always ready for operation it should be systematically and thoroughly inspected and looked after.

For this purpose, proceed as follows:

1. Check regularly the operation of the station and adjust or regulate its separate assemblies, units and systems.
2. Carry out a systematic inspection of all assemblies, units and systems of the station.
3. Keep clean all assemblies units and wiring of the station. Dust, dirt and moisture can cause surface insulation, breakdown and current leakage.
4. Keep metal parts of the equipment free from corrosion.
5. Put right all troubles which are noticed in the course of operation or inspection of the station and record them in the Log Book.
6. During operation in winter keep the temperature inside the cabin at not lower than + $10^{\circ}C$ following the instructions prescribed in Part 2, Chapter 9.

During preventive servicing and repair :-

- do not alter the circuitry, wiring and layout of wires;
- do not replace faulty components by new ones whose performances do not comply with the specification;
- do not leave faults located in the station unrepaired or unclarified;
- do not make temporary connections in circuits;
- do not use non-standard tools;
- do not use acid instead of colophony when soldering;
- do not clean the slip-rings and brushes of selsyns and current collector with petrol or paraffin;

- do not use petrol, mineral oil or other rubber solvents for cleaning cables and rubber parts.

2. PREVENTIVE SERVICING

Preventive servicing includes inspection, checking, tuning and maintenance of the station.

Preventive servicing may be daily, weekly, monthly and annual (season). Daily, weekly or monthly preventive servicing is performed by the crew, the monthly servicing being carried out with the help of a repair shop. Annual (periodical) servicing is performed by the repair shop with the crew participating. When performing daily, weekly, monthly or annual servicing be careful and attentive especially while cleaning the units.

Never inspect and clean a great number of units at a time as it may largely complicate the discovery and removal of faults which may occur during preventive servicing.

Inspect and repair any one unit of the station, place it in position, switch on the station, make sure that the unit operates normally and, after that, inspect the next unit. Preventive inspections of the motors, amplidynes, relays and magnetic starters, current collector, antenna-feeder system, trailer and automatic air dryer should be made strictly as instructed under Section 4 of the present Chapter.

After the station has been inspected, switch on and check it in operation.

Daily Preventive Servicing

While servicing the station, proceed as follows:

1. Carry out the external inspection and clean the whole station: wipe off the cabin on the outside, the antenna pedestal and the chassis with a dry cloth to remove dust and moisture. In case of rain or snowfall remove water or snow from the cabin roof. Wipe off the cabin inner walls with a dry cloth, and the panels of the cabinets and units with a soft moist brush. Clean the scale and instrument glass with a soft cloth. Wipe the cabin floor

first with a moist and then with a dry rag.

Check earthing of the station.

During operation in cold season see that the cabin temperature is not lower than + $10^{\circ}C$ and the stove is cleaned of ash.

2. Check levelling of the antenna pedestal.

3. Check the operation and tuning of the station units and the station as a whole as instructed under Part 2, Chapter 3, and make prescribed adjustments, if necessary. Compare the station operating conditions with the data given in the Log Book.

4. Make sure that the lamps lighting the scales of selsyns, instruments and indicators are in good condition.

5. Check that the synchronous drive and the data transmission system are matched.

6. Check that the station is oriented properly.

Weekly Preventive Servicing

In addition to the measures taken daily, do the following:

1. Clean the cabin chassis, check for tightening of all nuts on the chassis.

2. Check the condition of grease in the jacks. Dirty grease should be replaced with fresh.

3. Check suspension of cables and see that there is no excessive sagging between the supports, breaks and sharp bends of the cable and damage to insulation. Check whether tyres are protected from the sun rays in summer time.

4. Check in winter the condition of the slip-rings of the current collector and the antenna pedestal selsyns and, if necessary, clean them.

5. Inspect visually the measuring instruments, check and, if necessary, adjust their pointer to zero.

6. Wipe from accessible parts of all units of the station and high-voltage insulators and the components under high voltage, dust, dirt and moisture with a clean dry cloth.

7. Check whether assemblies and mechanisms of the station are lubricated;

in case of need lubricate them as instructed in the Table (See Section 3 of the present Chapter).

8. Check the hermetic sealing of the antenna-feeder system and operation of the automatic air dryer. With the dryer off, the pressure should drop from 0.4 kg/sq.cm. to zero for at least 30 min.

9. Check that the cabin operational and emergency lighting is in proper condition.

10. Switch on the station and tune the units as instructed under Part 2, Chapter 3.

11. Check the friction couplings of the range mechanism for proper regulation (See Part 2, Chapter 10, Section 9).

12. Check the connectors of the power cable. If there is an evidence of heating check the condition of contacts, clean the burnt spots.

Monthly Preventive Servicing

Besides the measures taken daily and weekly, do the following:

1. Wipe the antenna pedestal and reflector and the chassis with a wet duster and then with a dry cloth after removing dust and dirt from all slots, openings and chinks. These operations should be done after each shipment of the station.

2. Check the condition of the trailer chassis and soundness of the pneumatic brakes and the stop light.

3. Check the level and quality of oil in the azimuth and elevation reduction gears (See Section 3 of the present Chapter).

4. Clean the slip-rings of the current collector and the selsyns as instructed under Section 4 of the present Chapter.

5. Clean the commutators of the amplidynes, drive motors and tachogenerators as instructed under Section 4 of the present Chapter.

6. Check the condition of contacts and end faces of the cores of all magnetic starters and relays (See Section 4 of the present Chapter).

7. Check for the soundness and proper regulation of the limit switches

of the electric braking circuit and mechanical limiters in the antenna pedestal.

Check interlocks in the transmitter cabinet. For this purpose:

- switch on high voltage without increasing it;
- by opening the transmitter cabinet doors in succession, make sure that bias voltage and high voltage are off. Slight tapping of the transmitter cabinet closed doors should not cause accidental disconnection of voltage.

8. Inspect and clean the air filters of the fans in the main control board and the transmitter cabinet.

9. Inspect all the units of the main control board beginning from the upper unit and thoroughly clean them of dust (with the help of bellows or blow-gun). While inspecting visually:

- check the strength and reliability of solderings, contacts and mechanical joints;
- check for evidence of damaged, cracked or burned components, wires, insulators, leaky capacitors, transformers etc.
- check for traces of corrosion;
- check for soundness of contact blades of the unit connectors;
- check the condition of the relays in the units.

After finishing the above operations on one unit, place it in position and check the unit for energising it and all systems (units) of the station whose operation may be affected by the unit under check. Having ascertained that the unit behaves normally in the system, switch off the station and start inspecting the next unit.

Wipe carefully the compartments from which the units have been removed first with a slightly damp and then with a dry cloth.

10. Inspect and clean the transmitter, air dryer, antenna-feeder system (on the outside), control cabinet, amplidyne cabinet control panel, antenna pedestal, external boards of dust and dirt.

11. Check voltages across the monitoring jacks of the units in accordance with the data specified in the Log Book.

12. Make thorough inspection of contact surfaces of the antenna head feeder and wash them with alcohol.

13. Inspect and lubricate the fast rotating joint of the feeder line (with grease, CIATIM 201).

Note: Preventive inspection, washing and lubrication of azimuth and elevation slow rotating joints and all sections of the feeder line, with the exception of the reference voltage generator sleeve, are performed depending upon the operating conditions but not less than twice a year.

14. Pre-age the next magnetron from the spare parts set as instructed under Part 2, Chapter 10, Section 3. Each magnetron should be pre-aged once every four months.

15. Lubricate the station assemblies as instructed under Section 5 of the present Chapter.

16. Paint worn surfaces of the station and tools from the spare parts set.

17. Inspect, clean and lubricate spare parts, tools and accessories.

18. Inspect and weigh the fire extinguisher, type OU-2. Its weight should be 6.2 - 6.3 kg.

19. Switch on, check and tune the station as instructed under Chapter 3. The station operating voltages obtained during tuning should be recorded in the Log Book.

20. Check the operation time of the time relay.

21. Measure the current of the discharge valve as instructed under Part 2, Chapter 10, Section 4 "Replacement and Selection of Discharge Valve RR-5".

22. Check for matching of the electrical and optical axes of the antenna and check the station in elevation as instructed under Part 2, Chapter 4.

23. Check the range zero indication (See Part II, Section 2, Chapter 3, Point 4) and, if necessary, set it as instructed under Part 2, Chapter 10, Section 11.

Annual Preventive Servicing

In addition to the measures taken every month, do the following:

1. Overhaul the chassis and jacks of the trailer as instructed under the present Chapter.

2. Clean and lubricate the electrical machines according to the instructions on preventive maintenance of the electrical machines (Section 4 of the present Chapter).

3. Clean and lubricate the station assemblies according to the instructions on lubrication (Section 3 of the present Chapter).

4. Dismantle, clean and lubricate all the elements of the feeder line according to the instructions on preventive maintenance of the antenna-feeder system (Section 4 of the present Chapter).

5. Check the parameters of the station, its units and assemblies (See Chapters 10 and 11, Sections 4 and 5).

6. Check the condition and completeness of the spare parts set.

7. Check the performances of the spare parts set valves with the help of a valve tester. The valves that cannot be checked with the tester should be checked during operation of the station.

8. Clean the relays contacts, magnetic starters, buttons and contacts of the door interlocks in accordance with the instructions on preventive maintenance of separate units and elements of the station (Section 4 of the present Chapter).

9. Check fuses for condition and rated values.

10. Check the measuring instruments for soundness and accuracy.

11. Clean or replace the filters, blow out the solenoid valves and renew the diaphragm of the automatic air dryer compressor (See Section 4 of the present Chapter).

12. Tune and adjust the station as instructed under Part 2, Chapter 10.

All operations done and the station tuning data should be entered in the corresponding sections of the Log Book.

3. LUBRICATION OF STATION DURING OPERATION

The reliable and trouble-free operation of the mechanisms is also dependent upon timely and proper lubrication of the moving parts.

Grease minimizes the wear of parts and prevents corrosion on the

surfaces of parts having no protective coating. Besides grease reduces noise, makes heat dissipation occurring as a result of friction more effective, protects the bearing assemblies from dust and other foreign matter.

When operating the station, follow the Instructions on lubrication given below.

1. Station arriving from the manufacturing plant is lubricated, and therefore does not require lubrication prior to being put in operation.

2. In the course of operation each system and assembly should be inspected periodically for evidence of grease and corrosion on rubbing parts and on inoperative parts of components unprotected by coatings.

3. Prior to lubricating wipe all units and assemblies on the outside with a clean cloth. After sliding the units out of their mounting places remove dust and dirt collected on the inner parts of the units and assemblies.

4. The mechanisms should be lubricated with the station switched off in accordance with the Table presented below. [See Page 82].

5. While inspecting systems, units, assemblies and mechanisms of the station give special attention to lubrication of helical, toothed, worm gears and ball bearings. Remove thickened or foul grease. For this purpose wipe the components first with waste soaked in aviation petrol and then with a dry cloth. After that coat them thinly with grease.

6. Lubricate by means of a brush or cloth wound on a stick and see that the brush hairs or lints do not get into the mechanism. Never lubricate directly with the fingers.

After the gears, differentials, bearings have been lubricated turn the mechanisms in both directions to distribute grease more evenly. Remove excessive grease. Grease should not come on the components which are not to be lubricated.

7. If the components are found to be attacked by corrosion, wipe thoroughly the affected place with clean paraffin moistened waste. After removing corrosion wipe the component once again with a clean dry cloth and coat the entire surface with a film of grease. If corrosion cannot be removed in this

way make use of paste GOI. Never use files or emery paper. It should be borne in mind that even small corroded places under grease coating will widen and may make the component unserviceable.

8. When inspecting units and assemblies of the station use a portable lamp provided in the set of spare parts, tools and accessories.

9. Grease and petrol should be kept in clean and dry cans with caps tightly closed.

10. During frequent moves lubricate the chassis whenever necessary.

4. PREVENTIVE MAINTENANCE OF SEPARATE UNITS AND ELEMENTS OF STATION

Instructions on Preventive Maintenance of Electric Machines

During operation of the electrical machines special attention should be given to their cleanliness, condition of commutators and brushes and lubrication of bearings.

General Instructions on Cleaning

Check every month general condition of the motors and selsyns. Keep the commutator and the entire motor free from dust by blowing them off with the help of hand bellows from the set of spare parts, tools and accessories or the truck compressor hose for pumping up the tyres.

If moisture or oil is found on the outside of the motor wipe it dry or remove, if necessary, and wipe in accessible places, then dry it at temperatures of 60 to 80°C for 10 to 15 hours.

If rust is detected on the motor parts, remove it and wipe dry the cleaned place. If this part was painted before, renew the painting.

Inspection of Commutators and Brushes

Carbon deposit or dirt must be avoided on the commutators or brushes. Check their condition every month. In case of excessive wear or burning of the brushes they should be replaced from spares. The seated brush face should make up not less than two thirds of the entire operating surface. The least permissible length of a brush must be three times as wide as the clearance between the commutator and brush holders. While inspecting the

brushes note their position relative to the brush holders and then set them as they were before, otherwise the brushes will be wrongly seated with respect to the commutator.

Should the brushes be replaced, seat the new brushes by running the motor for five or six hours. After that remove the brush, wipe it with an alcohol-moistened rag and before fitting the brush do the same with the commutator.

The properly seated and fitted brush, if the commutator is sufficiently true and smooth, should give off no sparks or produce light sparking. No heavy sparking is allowed. The degree of brush sparking is regulated by changing the brush pressure.

While inspecting the brushes wipe them with an alcohol moistened cloth.

Clean the commutator with a chamois leather, clean rags or cheese-cloth soaked in alcohol and wrapped round a stick.

The commutator is cleaned through the ports in the end shield while the motor is running. In case of excessive burning of the commutator, clean it with a fine sand cloth fitted on a stick. After that wipe the commutator and brushes thoroughly with a rag soaked in alcohol. If carbon deposit cannot be removed in this way and the motor is sparking heavily, replace the motor.

Inspection of Selsyn Slip-Rings

Contamination of the selsyn slip-rings results in poor contact between the brushes and slip-rings.

Clean the slip-rings with an alcohol-moistened rag or cheese-cloth wound on a thin stick when the rotor is rotating. Do not finger the slip-rings as this fouls them and produces greasy spots.

Do not bend up the brushes as it may result in abnormal operation of the selsyn. The selsyn brushes do not need special cleaning.

Inspect and clean the selsyns every month.

Do not remove the selsyns located in the antenna pedestal together with cups as it disturbs factory adjustment of the operating clearance between the gear teeth of the drive and selsyns.

Lubrication of bearings of electric machines

Grease the motor and selsyn bearings approximately twice a year and renew it during annual preventive service. Lubricate the bearings of the motors with grease, grade CIATIM 201 or GOI 54 and those of the selsyns with instrument oil, grade MWP/GOST 1801-51 or ATM/TU 01563-53 .

Pack grease in the selsyn bearings by means of lubricating guns. Remove or push the removable bearing caps aside from the frame if complete removal is hampered with a coupling or gear fitted on the shaft. Remove old grease, if possible, and fill the bearing with fresh grease then place the cap in position and secure it with screws. The motors and selsyns not provided with removable caps should be lubricated through the clearance between the shaft ends and the frame.

Never remove the caps holding the selsyn bearings.

Special care should be taken to lubricate the bearings of the drive motors located on the antenna pedestal and the bearings of the amplidynes.

To lubricate the bearings remove the drive motors, unscrew screws 1 (Fig. 250), remove cap 2 together with packing ring 3, remove coupling 4, take out key 8 and remove oil-splashing disc 5. Unscrew bolts 6, remove flanges 7 covering access to the bearing.

After lubricating the bearings replace the parts which have been removed. Before removing the coupling note their setting on the shaft, to avoid additional adjustments during assembly of the parts.

To lubricate the bearings of the amplidyne, unscrew screws 1 and 2 (Fig. 251), remove cap 3 and housing 4, remove fan wheel 5, unscrew bolts 6 and remove flanges 7.

Clean the bearings of old grease and lubricate them with fresh grease by means of a stiff brush.

After lubrication replace the parts which have been removed.

To make a complete change of grease in the bearings of the motors and selsyns remove the flanges holding the bearings, wash them in clean petrol to remove the remnants of old grease and blow them off with hand bellows.

Then fill the bearings with fresh grease and replace the flanges.

If, while inspecting the motor, wear of the bearing is noted in the form of increased uneven noise, screeching or knocking in the bearing, the motor should be replaced or repaired.

Checking Motors for Proper Operation

After the motors have been repaired or replaced check them for proper rotation:

1. The direction of rotation of the amplidynes must correspond to the arrows engraved on the housing of their motors.

2. Correct rotation of the fan motor of the main control board is determined by the direction of fan impeller rotation. When looking at the impeller from the ventilation port side (the port is located in the side cover of the control panel) its blades must rotate from top to bottom.

3. The direction of rotation of the transmitter fan motors M25-1, M25-2 must correspond to the arrows engraved on the fan housing.

Remark: In station of earlier design the direction of air flow is marked with an arrow on the fan housing. When checking correct connections of the cooling fans' motors, attention should be paid to the transmitter cabinet cooling fan which should blow the heated air from the cabinet out and under the trailer cabin; also to the magnetron and modulator valves' cooling fans which should produce an intense flow of air.

Correct connections to the motors of the cooling fans can be checked by the intensity of air flow at the outlet of the impeller. With wrong connections to the motors of centrifugal fans, only the intensity of air flow is affected, but the direction remains the same.

4. Correct rotation of the cabin fan motor is determined by the impeller direction of rotation. The impeller must rotate counter-clockwise (when looking from the cabin through the window in the plating of the amplidyne cabinet) and force air into the cabin.

In case of counter-rotation of the motors interchange the two wires feeding the motors at the point of connection.

Wrong direction of rotation of the ventilator motors may be the cause of faulty cooling and lead to damage of the station; wrong direction of the amplidyne rotation will affect the operation of the antenna positioning system.

Instructions on Preventive Maintenance of Relays and Magnetic Starters

The relays and magnetic starters must be inspected and cleaned every month. In doing this, proceed as follows:

1. Wipe thoroughly all accessible parts of the relays and magnetic starters twice, first with a slightly moistened and then with a dry rag. Then blow them off by means of hand bellows.

2. Check for reliable connection of wires and fastening of the relays and magnetic starters.

3. Clean carbon deposit found on the contacts with the help of a stick covered with chamois leather or woollen cloth coated with paste GOI. In case of bulged metal or burnt places clean the damaged places by first filing them with a barette file and then by polishing with paste GOI. Dismantle the relays only when required.

4. Once every six months (in spring and autumn) dismantle and perform additional preventive maintenance of the magnetic starters located on the control panel and in the transmitter cabinet. For this purpose, proceed as follows:

- withdraw cotter pin 8 positioned in a hollow of magnetic starter moving part 2 (Fig.252) and drive out pin 9 securing the movable part to the stationary one;
- separate starter movable parts 2 from stationary part 4, remove the contact holders of the movable part as follows: slightly lift the spring support rod and by turning it through 90° place it in the longitudinal recess: remove the core upper part;
- wipe all non-lubricated parts of the magnetic station first with a slightly moistened rag, then with a dry one;
- remove old grease from the core end faces with a rag slightly soaked in aviation petrol;
- remove carbon deposit on the contacts as described above;
- wipe core end faces with a rag coated with grease CIATIM 201;
- assemble the magnetic starter.

5. Once a year dismantle the control cabinet magnetic starters and perform additional preventive maintenance.

For this purpose proceed as follows:

- open the control cabinet cover by unscrewing the holding screws;
- remove the spark extinguisher by pushing it up after unscrewing the clamps;
- separate the movable part of the core from the starter rod after unscrewing two screws.
- remove carbon deposit in way described above;
- wipe the core end faces with a rag coated with grease CIATIM 201.
- assemble the magnetic starter.

Remark: For assembling and dismantling of the magnetic starters use screwdriver A-4,5, pliers (in box 3), and spanner 911 (in box 1-1).

When dismantling the magnetic starters and performing additional preventive maintenance check the auxiliary interlocks for proper setting. In doing this, lift the movable system of the magnetic starter (1, Fig.214) until it comes to a stop and lower it down slowly. In this case the upper pair of auxiliary interlocks 7 must open after a gap of at least 3 mm is obtained between the main (operating) contacts 6 of the magnetic starter.

If the size of the gap is different proceed as follows:

- slacken screw 8 securing the auxiliary interlocks;
- lift the magnetic starter movable system until it comes to a stop and move the body of the auxiliary interlocks down until the locking pin of the interlock rod touches its plastic body;
- fix the auxiliary interlocks' body in this position, release the movable system and check the interlocks for proper adjustment as mentioned above.

Note: Adjustment should be made with the station fully de-energised.

Instructions on Cleaning the Current Collector

The current collector slip-rings should be cleaned not less than once a month, as follows:

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1. Remove the upper and lower parts of the housing of the antenna pedestal azimuth compartment (on the stove side).

2. Remove the cover from the current collector after screwing wing nuts off bolts 6 (Fig. 184).

3. Unscrew the 6 bolts 7 securing the pressure plates 4 with brush clamps and gently remove them, taking care not to damage the brushes and guiding pins.

Wrap the plates with the brushes in clean paper or cloth and carefully put them aside.

4. Put a surgical tape of 10 mm wide and about 1.5 m. long between the body and the current collector, care being taken not to scratch the collector slip-rings.

To run through the surgical tape, pass one end 15 to 20 cm. long between the two insulating rings closely to the current collector ring and rotate the current collector by the power gear of the azimuth drive until the tape appears between the body and the current collector column.

5. Slightly moisten part of the surgical tape in alcohol and by moving the tape back and forth clean the slip-ring of dirt and dust (of ice, hoar-frost in winter) and then clean it in the same way with a dry portion.

6. After cleaning one slip-ring pass on to the next (cleaning should be started from the extreme upper ring). For this purpose, slacken the surgical tape and throw it over from one slip-ring to another.

Clean all the current-collector slip-rings using this method.

7. Turn the antenna by 180° (taking it by the azimuth drive power gear) and repeat slip-ring cleaning as instructed under Items 4 - 6.

8. After the current collector slip-rings have been cleaned, replace the pressure plates and brushes and see that each brush is positioned in the middle of the slip-ring. If not, loosen the two bolts 8 securing the brush clamps to the plate and position it so that the brush is in the middle of the ring. Then screw up the bolts.

9. Having re-placed the pressure plates check the pressure of each brush on the slip-ring, which should be 250 - 350 gr.

Pressure should be checked by means of a dynamometer included in the station set of spare parts, tools and accessories (box 4). Hook the dynamometer to the plate where the brush is secured, making sure that the dynamometer axis is at right angles to the brush plate. By pulling gently on the dynamometer pull the brush away from the ring and take the reading on the dynamometer.

If dynamometer readings deviate from normal adjust the brush pressure. For this purpose unscrew two screws fastening the spring to the pressure plates brush clamps and remove the spring. Slightly straighten the spring in the point of bending in case of increased pressure (more than 350 gr.) or slightly bend it in case of decreased pressure (less than 250 gr.). Then place it in position.

10. Switch on the station and check:

- that the antenna pedestal smoothly moves in azimuth and elevation during circular scanning and observe the scales of the corresponding fine and coarse receiving selsyns;
- the operation of the automatic tracking system by a landmark;
- the operation of the electric braking circuit in elevation.

After that install and fasten all previously removed covers.

Note: To clean the current collector use: wrench, 911 (in box 1-1) a surgical tape (in box 4), rectified alcohol (in box 2) and grinding paper (in box 3)

Instructions on Preventive Maintenance of Antenna-Feeder System

To ensure normal operation of the antenna-feeder system the contact surfaces on the feeder connections should show no traces of carbon deposit, corrosion and dirt and the inside of the feeder should be clean. Therefore, for preventive maintenance purposes completely dismantle the antenna-feeder system twice a year. In doing this proceed as follows:

1. Inspect thoroughly all the contact surfaces of all the feeder sections.

2. Wash all the sections. For this purpose plug one section end and pour in 50 - 100 cu.cm. of alcohol in the section. Then plug the second end and shake the alcohol for five minutes. After shaking remove the plugs and

pour out the used alcohol into an empty vessel and dry the section for five minutes. After washing the feeder thoroughly filter the alcohol for further use.

3. Wipe the contact surfaces and other areas of the feeder (the inside of the T-junction, contact connections, etc.). Clean off traces of corrosion, carbon deposit and dirt with a clean cloth moistened with alcohol.

While cleaning the feeder do not use emery cloth as it causes damage to the coating.

In case the feeder breaks down and other faults arise find the point of breakdown or fault and repair it.

During preventive maintenance or repair of the antenna feeder system follow the instructions below:

1. Do not remove and disconnect the reference voltage generator (GON) as it will disturb the factory setting of the antenna electrical axis and consequently the operation of the automatic tracking system.

2. Do not withdraw the sleeve from the reference voltage generator as it will cause faulty operation of the automatic tracking system. In emergency cases the antenna-feeder system may be dismantled. In this case note the position of the sleeve relative to the reference voltage generator rotor. When replacing see that the notches are brought in line. If they are, the sleeve will assume the initial position.

3. Inspect and repair in dry weather in covered premises only. In emergency cases the antenna-feeder system may be inspected or repaired in field conditions during rain or snowfall. In order to protect the feeder from moisture, dismantle the feeder system under a tarpaulin using a portable lamp. After the operations are over remove the tarpaulin and blow the feeder with dry air from the automatic air dryer for 15 to 20 minutes.

Preventive Maintenance of Fast-Rotating Joint

Once a month (and during every dismantling) make preventive inspection and lubricate the bearing which centres the inner feeder of the fast-rotating joint in the following sequence:

1. Disconnect feeder section 17 (Fig.177) connecting part of the fast-rotating joint with the slow-rotating joint (inclined feeder); remove the antenna head.

2. Unscrew six bolts 24 fastening the fixed section of the fast-rotating joint to the reference voltage generator and disconnect it.

3. Carefully remove old grease from pin 8 (Fig. 51) in the bushing of sliding bearing 10 with a clean rag soaked in aviation petrol and wipe dry with a clean cloth.

4. Fill the sliding bearing with grease CIATIM 201 using a thin wooden stick. See that the grease does not get on the inner surface of the external conductor and the outer surface of the inner conductor of the feeder. Remove the traces of grease with a dry rag, then wipe with a clean rag soaked in alcohol.

5. Reassemble the fast-rotating joint. See that the pin is not damaged when it goes into the sliding bearing.

Full Dismantling of Feeder System

To accomplish full dismantling of the feeder system, slide the transmitter forward out of the cabinet. For this purpose :

1. Remove the heterodyne unit by disconnecting the radio-frequency cable connecting it with the mixers.

2. Open the side plating of the transmitter cabinet.

3. Disconnect the tube supplying dry air from the feeder.

4. Remove feeder section 1 (Fig.47) connecting the azimuth slow-rotating joint with the T-junction.

5. Separate movable plate 15 with magnets from the antenna pedestal base plate by unscrewing four fastening bolts.

6. Disconnect power, radio-frequency, earth cables and conductors from the side transmitter interlocks.

7. Remove the four bolts and unscrew two nuts fastening the transmitter to the frame on the rear.

8. Remove the branch pipe of the input air line of the magnetron cooling

9. Carefully slide the transmitter forward out of the cabinet by two-thirds of its length having put a wooden block under its front part, taking care not to damage the cables.

After the above preparatory operations pass on to dismantling of the feeder system. For this purpose, proceed as follows:

1. Remove inclined feeder 6 (Fig.47) connecting the fast-rotating joint with the elevation slow-rotating joint.

2. Remove bracket 16 holding the fixed section of the elevation slow-rotating joint.

3. Slacken bolts 17 clamping the elevation slow-rotating joint.

4. Disconnect the elevation rotating joint by turning the outer tube counter-clockwise with a wrench.

5. Remove the elevation slow-rotating joint from the tube.

6. Remove covers 10 (Fig.177) from the side and top recesses of the antenna pedestal.

7. Unscrew the nut of connecting angle 4 through the side recess using a wrench and remove it through the top recess (Fig.47).

Further dismantling is carried out inside the transmitter cabinet.

8. Remove bracket 18 (Fig.47) holding the fixed section of azimuth slow-rotating joint 2.

9. Unscrew the bolts clamping split centring flange 21. Unscrew the bolts clamping the flange to the antenna pedestal, remove its free part. Holding the feeder, remove the other part from the pins.

10. Carefully put the azimuth slow-rotating joint on the floor and unscrew central feeder 3 to separate it from the azimuth slow-rotating joint 2.

11. Remove the central feeder from the antenna pedestal.

<u>Preventive Maintenance on Slow-Rotating Joints</u>

Preventive maintenance and lubrication of the elevation and azimuth slow-rotating joints during full dismantling of the antenna-feeder system should be performed in a repair shop.

In doing this, proceed as follows:

1. Unscrew screws 3 (Fig.50) fastening the movable part of the joint to the body of the fixed section of the slow-rotating joint.

2. Disconnect the movable section from the fixed one.

3. Unscrew the lock nut and nut 5 holding the bearings on the bushing.

4. Remove the feeder bend from fixed section sleeve 15.

5. Remove bearings 1, 2 and sleeve 10 from the body.

6. Wash the bearings, sleeve, the inner part of the body with aviation petrol and after drying them out, lubricate with grease CIATIM 201.

7. Clean and slightly lubricate packing collar 7 with grease CIATIM 201.

8. Reassamble the slow-rotating joint. Then reassemble the feeder. During assembly see that the contact enters the seat of the inner feeder.

When installing the azimuth slow-rotating joint and the central feeder see that the insulators are in the same plane, for which purpose use template AEG 859.000 which can be found in the station spares locker.

Wrong assembly of the feeder system causes burning of contacts and faults in the system.

After the antenna-feeder system has been assembled, switch on the station and check its operation. If, when increasing high voltage, a characteristic breakdown noise (peep) is heard in the feeder line, switch off high voltage immediately and check the assembly of the feeder system.

Note: To perform preventive maintenance of the antenna-feeder system, use a wrench, 8 x 9, a special wrench for milled nuts of the slow-rotating joint, two-end screw-driver, a socket wrench S - 9, a feeder system wrench and socket wrench 2.7 - IS-16, a feeder system template and a socket wrench, 22 x 27 (in box 7); an adjustable wrench and screw-driver A3.5 (in box 3); special wrenches (in the antenna head bracket); dusters (in box 4) and rectified alcohol (in box 2).

Instructions on Ensuring Watertightness of Antenna Pedestal and Trailer Cabin

Antenna Pedestal

After transporting the station and after each preventive inspection and maintenance involving dismantling of the external part of the antenna pedestal, ensure watertightness of the latter by coating the areas of probable penetration of moisture with water proof paste.

When applying the paste, proceed as follows:

1. Coat the covers of the elevation selsyn drive at points 1, 2, 3 (Fig.253) and point 4 (where the plate is connected with the housing).

2. Coat point 5 of connection of the elevation slow-rotating joint with the horizontal section of the feeder.

3. Coat in the elevation motor drive:

   - Point 10 where the tachogenerator is fastened to its cover 9.
   - Point 11 of connection of the cover obstructing access to the limit switches.
   - Point 12 of connection of the end cover with the drive housing.
   - The point where the pipe union of limit switches is installed.

4. Coat points 14 and 15 of connection of the covers closing the assembly windows.

5. Coat points 16, 17, 18, 6, 7 and 8 of component connection.

   The specified points should be coated with paste as follows:

   (a) Roll the waterproof paste in the form of a narrow cylinder 2.5 or 3 mm in diameter (if necessary slightly warm the paste to make it soft enough).

   (b) Place the paste cylinder on the point of connection of components, on the outside.

   (c) Coat the place of connection with a paste seam, 3 to 6 mm wide, and up to 2 mm thick after slightly warming up the paste with a soldering iron.

   (d) Remove the excess of the paste with a wooden blade and without disturbing the rubber packing gaskets and paint coating, clean the surface of the component near the seams with a petrol-moistened cloth.

Coat the fastening screws and bolts of the above connections with waterproof paste.

The places in Fig. 253 indicated by reference numbers 1, 3, 4, 6, 7, 8, 9, 10, 16, 17, 18, should be coated with waterproof putty prepared according to prescription BEO 045.042. The places indicated by reference numbers 2,

5, 11, 12, 14, 15 should be coated with waterproof paste prepared according to prescription BEO 045.069.

Trailer cabin

Coat the fastening bolts of the front hatch (after the operations involving opening of the hatch) with waterproof paste.

Instructions on Care, Dismantling and Preventive Maintenance of the Chassis, Towing and Turning Gear

Care of turning gears boils down to periodical checking of all types of swivels, their lubrication and checking of the required toe-in angle. The fastening nuts, plugs and pins must be locked. The tightening of end piece nuts should be checked during weekly preventive inspection. Every 1000 km. of running check and, if necessary, tighten the nuts of the ball pins and lubricate the turning bar swivels with solid oil. When replacing the turning gears, set the required wheel toe-in angle.

Wheel Suspension

Care. Care of the wheel suspension consists in periodical checking of the clearance between the upper stop of the bracket and the stop of the torsion arm. The absence of clearance is evidence that the torsion bar is defective and it should be replaced. The rubbing parts of the torsion cylinder and bracket bushings must be lubricated according to the instructions on lubrication.

Dismantling. Any of the four assemblies of the torsion-bar suspension must be dismantled as follows:

1. Free the torsion bar from the load by jacking up the trailer so that the wheels are not touching the ground.

2. Remove the wheel. Remove the cap from the protruding end of the torsion cylinder after unscrewing the fastening bolt. Knock out the torsion bar from the bracket slits by light taps, using a hammer and a copper drift, and remove it. The second cap on the other end of the torsion cylinder need not be removed.

3. Remove the torsion cylinder from the bushing of the frame bracket.

As the cylinder goes out of the torsion arm, the latter should be supported.

When reassembling, the following rules should be observed: the cylinder with arm must easily rotate in the bushings of the frame bracket between the stops. During the next setting of the torsion bar the clearance between the upper stop of the bracket and the arm stop should be 10° (when unloaded).

Wheels

Care. Care of the wheels consists in checking the fastening of the steering knuckles and steering arms (the fastening nuts of the steering arms are locked in the knuckles) when performing routine inspections and servicing of the trailer. The steering arm cone must be tightly fitted into the cone seat of the torsion arm (by grinding in). When performing check inspection en route, check the temperature of the wheel hubs which should not exceed 60°C. Every 900 or 1000 km. check and, if necessary, adjust the bearings of the wheel hubs, and every 5500 to 6000 km. and annually, replace grease in the hubs and adjust the bearings.

While replacing the grease, with the hubs removed, check the knuckle axial play by setting adjusting shims 20 (Fig.221) on the king pin between the upper projection of the knuckle and the axle. The play should not be more than 0.25 mm. The bushings of the king pins in knuckles and the thrust bearing should be lubricated with solid oil every 500 km. of running. Besides, each time when inspecting and servicing the trailer, check the condition of tyres and tightness of the wheel fastening nuts and tube pressure (by pressure gauge), as the service life of tubes is largely dependent upon the care, observance of assembly, dismantling instructions, correct towing and technical condition of the trailer.

The tyres should have no local bulging and other imperfections; the patches must not come off. Should the pressure in the tubes increase through heat during running do not bleed the air. Check the pressure after the tyres get cold. If the pressure is lower than normal inflate the tyres and make sure that the trailer does not run on flat tyres.

Adjustment of wheel bearings. To adjust the wheel bearings (Fig. 222), proceed as follows:

1. Jack up the trailer and check the tightness of the bearings.

2. Remove hub cap 6, care being taken not to damage the gasket between the cap and hub.

3. Bend off plate washer 7, unscrew locking nut 8 and remove the washer 7 and locking ring 9.

4. Slightly slacken nut 10 and by turning the wheel make sure that it rotates freely and smoothly without jamming (without pumping the brakes) in the bearings and in the gland.

5. While turning the wheel tighten the nut so that there will be increased braking; then unscrew the nut one-eighth or one-sixth of a turn and check the wheel for easy running.

6. Place the locking ring and plate washer in position and tighten locking nut 8.

If the wheel is properly adjusted it should run freely and true and there must be no appreciable axial play of the hub. In case of axial play or when the wheel rotates with difficulty adjustments should be repeated.

7. After all adjustments have been made, fix locking nut 8 by washer 7, grease the hub and put cap 6 on the gasket. Adjust the other wheel bearings in the same order.

8. Check for correct adjustment while in motion. If the bearings are properly adjusted the hub may slightly run hot. However, hub heating, easily felt by hand, is harmful and should be corrected by repeated adjustment.

Setting of front wheels and king pin. The setting of the front wheels and king pin relative to the trailer support plane is characterised by the following data: wheel camber is 1°, toe-in is 0.5° and king pin angle of inclination is 8° (Fig. 254).

The front wheel angles of setting may change in the course of operation of the trailer, therefore they should be periodically checked and adjusted to normal. The increase of play in connections of the steering knuckles with

torsion arms and in the wheel bearings as well as disturbance of wheel and king pin angles of setting reduce the service life of the trailer chassis during its operation.

The toe-in angle should be checked every 2500 to 3000 km., while the wheel camber and the king pin angle of setting every 5500 to 6000 km. and when the wheels take heavy knocks going over a bump or the suspension components are damaged or replaced.

A change of king pin inclination angles and wheel camber is caused by bending of the torsion arms or distortion of the chassis frame side members and also by wear of king pins and their bushings in the steering knuckles. The toe-in angle is disturbed if the torsion arms, turning bars, knuckle steering arms are bent out of shape and if swivels are worn out.

Before checking the angles check the condition of the torsion arms and possibility of their being bent, play in the steering knuckles and adjust the wheel bearings. When checking, place the trailer on flat, solid ground with the wheels parallel.

Check the king pin angles of inclination and the wheel camber with special instruments. The wheel camber can also be checked with a big square by placing it against the wheel centre as shown in Fig.254, a.

The space difference between the wheel rim face and square (A-B) should be 5 - 6 mm. To avoid mistakes caused by accidental surface irregularities of the rim, checking should be done with both wheels in three positions.

Note: The king pin side inclination and the wheel camber are obtained by a definite design of the front and rear axles and are not adjusted in the course of operation, but checked as described above. When the king pin side inclination and wheel camber are disturbed, correct or replace the damaged components.

The toe-in angle is adjusted by varying the length of the turning bars. Before adjusting the toe-in angle, place the front wheels in a position corresponding to the straight line motion of the trailer and determine the toe-in by measuring minimum space between the side surfaces of the tyres at the level of the wheel axle at the rear (A) and front (B). With the toe-in normal, the difference between distances A-B should be 18 to 22 mm (Fig.254, b).

If the toe-in value differs from that mentioned, adjust as follows:

(a) Release the clamping bolts on the end pieces of both turning bars.

(b) Rotate the bar (screw it in the end piece when the toe-in is large and out when the toe-in is small) and change the space between the swivels in its end pieces so that the toe-in value is normal.

(c) Tighten the clamping bolts of both end pieces.

Wheel Brakes

Care. Care of the wheel brakes consists in checking the fastening of the brake components, tightening the nuts of the brake anchor pins, cleaning the brakes of dirt and periodic adjustment.

Every 5500 to 6000 km. remove the brake drums, thoroughly clean the brake components of dirt and check the brake shoe linings, the surface of the drums and springs. When the linings are greatly worn out replace them, when the brake shoes are oiled wash them and correct the fault (usually oiling is caused by damage to the glands in the wheel hub).

When assembling the brake, coat brake anchor pin surfaces thinly with solid oil. Every 500 km. coat the shafts of the expansion cams (in the brackets) with solid oil. Lubricate adjusting worm gears of the arms with graphite oil when assembling.

In case of dismantling and subsequent assembly of the brake system make full adjustment of the brakes, bearing in mind that, if the clearance between the brake shoe and drum is chosen correctly, the brake drum heating should not exceed 50°C at the trailer speed of not more than 25 km/hr for a period of 10 min.

Adjustment of wheel brakes: because of friction between the brake shoes and the drum their surfaces are gradually worn out and this results in an increase of the clearance between them. This increase makes the rod travel further and deforms the diaphragm of the brake chamber when the brakes are applied.

To facilitate checking of the clearance value which should not exceed

0.25 to 0.4 mm in the middle part of the brake shoes if the brake is properly adjusted, the brake drum is provided with access ports.

To adjust the brakes, proceed as follows:

1. Jack up the trailer so that the wheels are off the ground and check whether the wheels rotate easily.

2. Measure the clearance in the mid part of the lining (Fig. 255) with the help of a feeler gauge.

3. Turn the shaft of the expansion cam by rotating the arm worm clockwise so that the wheel rotated manually is slightly braked (Fig. 256).

4. Rotate the expansion cam worm counter-clockwise until the wheel starts rotating freely.

5. Check the clearance between the brake shoe linings and the brake drum.

6. Press the brake pedal when the wheel is rotating, check the brake action and measure the travel of the brake chamber push rod. The travel should not exceed 40 mm. NEVER ADJUST THE WHEEL BRAKE BY CHANGING THE LENGTH OF THE BRAKE CHAMBER ROD BY ROTATING ITS YOKE.

> Note: An increase of the push rod travel is accompanied by an increase of an amount of energy consumed for distortion of the brake chamber diaphragm, which results in a decrease of force pressing the brake shoes to the brake drum. Therefore, the travel of the brake chamber push rods on all wheels should be equal.

When assembling the brake (after replacing the linings) make full adjustment and set the brake shoes concentrically relative to the brake drum. This adjustment is made by means of pins, the supporting neck of which is eccentric relative to the fulcrum pin fixed to the brake anchor plate bracket. Therefore, turning of the pin causes a displacement of the brake shoe fulcrum pin in relation to the brake drum, while during partial adjustment the fulcrum pin remains in the initial position.

During full adjustment, by rotating the worm of the expansion cam arm and turning the anchor pin (with its fastening nut slackened) press the entire surface of the brake shoe lining to the brake drum and by holding this position tighten the nut fastening the anchor pin to the brake anchor plate.

After that set the desired clearance between the brake shoe and drum by turning the cam with the help of the worm. The action of the trailer brakes is checked while in motion: when the trailer moves at a speed of 20 km/hr on a dry asphalt road the braking distance should not be greater than 8 m., all the trailer wheels should be simultaneously braked without skidding.

Brake Rigging

Care. Care of the brake rigging consists in checking and eliminating the air leaks in connections, air lines and mechanisms of the rigging, in checking the fastening of the brake rigging mechanisms and components, the operation of the air distributor and in checking drain of condensation from the air container.

Before each journey check the pressure in the brake system as measured by the pressure gauge. If it is lower than 4.5 kg/sq.cm. raise it when the truck engine runs idle. Check the pressure in the system while in motion: it should be 7 to 8 kg/sq.cm. (the pressure rise from zero to 7 or 8 kg/sq.cm. at maximum revs should follow at most after two minutes).

Note: The brake system pressure may decrease for short periods in case of frequent repeated brake applications.

TO ENSURE AGAINST COMPLETE AIR CONSUMPTION DURING FREQUENT APPLICATIONS OF BRAKES DO NOT SWITCH OFF THE TRUCK ENGINE ON LONG DOWN SLOPES.

When pressing the pedal the pressure in the system should not sharply drop and as long as the pedal is pressed the pressure gauge pointer should not noticeably deflect. An appreciable pressure drop in this case indicates that air is escaping from the brake system. A sharp drop of air pressure to 2 - 2.5 kg/sq.cm. when the engine comes to a stop bears evidence of the air leakage as well. The leakage should be found and immediately corrected. For this purpose examine separately the pneumatic system of the truck and then connect and check that of the trailer. With the engine off and pedal released, the pressure drop in the brake system (as measured by the pressure gauge) from 7 or 8 kg/sq.cm. should not exceed 0.8 to 1 kg/sq.cm. during one hour.

A strong air leakage can be discovered by ear whilst a weak one by means of soap solution which should be applied to points arousing suspicion.

Air leaks through connections can be eliminated by tightening them.

In the absence of air leaks the cause of insufficient pressure in the brake system may be clogging of the truck compressor air filter, the oil-and--water separator filter and insufficient tension of the compressor drive belt or unsatisfactory operation of the compressor because of wear of its components. Each time when inspecting the trailer check the brake rigging together with the truck, making beforehand the required adjustments and testing the trailer brakes.

When the brake system operates normally it is necessary to drain condensation from the air tanks: every day in cold weather (in winter) and every 2500 to 3000 km. but not less than once a week. Every 1000 km. check the condition and fastening of the air pipes, air container, brake chambers and the air distributor.

By tightening or connecting flexible hoses to the brake chambers make sure that the wheels when turned through the angle of lock in either side do not make contact with the hoses.

To eliminate the contact, slacken the pressure nut on one end of the hose. Then by turning the hose about its axis set it in the desired position; after that, holding the hose tighten the union nut.

Checking and adjustments. In case the air bleeds through valves or the air distributor fails to operate (upon expiration of the guarantee period) remove the seals, dismantle it and check the condition of rubber packings. If the rubber packings are damaged they should be replaced.

When assembling the air distributor it is necessary to keep the reference clearance of 2.9 ± 0.5 mm between the rubber gasket and the outlet valve (Fig.257). Check the above clearance on the set (the air scoop body, a rod with an inlet and an outlet valve in assembly). For this purpose rest upper end A of the rod against a table surface and while pressing the air distributor body press the rubber ring of the inlet valve to the valve seat in the body. Measure the clearance in this position by placing a ruler on the under side of the outlet valve and determining the clearance between the

ruler and the body end face.

When assembling the valve, coat all the machined unpainted surfaces of the components, which do not make contact with the rubber components, with a film of petroleum jelly. Upon completion of the assembly test the air distributor in operation.

When the valve is dismantled in a repair shop it is desirable, after assembling, that the air distributor should be tested for hermetic sealing and serviceability.

To test for serviceability, proceed as follows:

1. Screw a plug with a pressure gauge in duct III (Fig. 224). Admit air of 1.5 to 2 kg/sq.cm. pressure from the air main to duct I and fill the air tank (of 35 lit. capacity) through duct II.

2. Connect duct I with atmosphere; the air in this case should come to duct III, which is registrated by a deflection of the pressure gauge pointer.

3. Admit air of at least 1.5 kg/sq.cm. pressure from the air main to duct I, the air escaping from duct III through duct IV, which is shown by the pointer of the pressure gauge located in duct III to zero.

To test for hermetic sealing, proceed as follows:

1. Connect the air container of 35 lit. capacity having air pressure of 5.5 kg/sq.cm. with ducts I and II of the valve. The air pressure drop in the air container should not exceed 1 kg/sq.cm. per 8 minutes (duct III should be connected with the atmosphere).

2. Connect duct II with the air container of 35 lit. capacity, 5.5 kg/sq.cm. when duct III is plugged and duct I is connected to the atmosphere. The air pressure drop in the air container should not exceed 1 kg/sq.cm. per 2.5 minutes.

Instructions on Care of Automatic Air Dryer

The automatic air dryer, type AD -220T, operates reliably with systematic care, preventive servicing and speedy repair of faults.

During the dryer operation, proceed as follows:

1. Watch the change of silica gel colour in the moisture indicator. The

silica gel should be coloured dark-blue.

Silica gel turning pink may reveal an increase in air humidity (turn the knob of governor DEW POINT toward reduction of air consumption), increased air leak in the line or failure of a drying chamber (check the dryer operation by the second drying chamber).

2. Check for evidence of strange noises in the air dryer.

3. Watch the air pressure as measured by the pressure gauge. If the pressure drops sharply, check for evidence of leaks and then open the compressor and inspect the diaphragm and valves. Correct troubles, if any.

Besides the above instructions on care of the dryer during operation, carry out preventive treatment of individual components listed below.

Compressor

1. Every 400 to 500 operating hours replace the diaphragm and lubricate the compressor bearings. To replace the diaphragm, disconnect the air pipes from the pipe connection, remove the compressor cover, screw the mushroom-type device out of the connecting rod, using a special wrench, and replace the worn-out diaphragm. When assembling proceed as follows:

- See that the diaphragm edges are not bent out of shape.
- See that the connecting rod, when the diaphragm is clamped by the disc, is in the extreme upper or lower position.
- Tighten the disc by bolts so that it uniformly presses the diaphragm.

2. After replacing the diaphragm, before trial starting of the compressor, turn the compressor belt once or twice by hand; it must rotate smoothly and the mushroom-type device should not strike against the disc. If the belt rotates with great difficulty or fails to rotate, dismantle the compressor and remove one or two shims from under the disc.

If the belt rotates freely turn on the electric motor and check the operation of the compressor. In this case:

- Metallic noise (with the exception of valve noise) should not be heard.
- A pressure gauge attached to the output pipe connection should read

from 0 and 3 kg/sq.cm. for a period not longer than 15 seconds (with air holes plugged).

3. Check the operation of the unloading valve. For this purpose plug one branch of the pipe connection and attach the pressure gauge to the other one. Switch on the compressor. As soon as the pressure reaches 3 kg/sq.cm. switch off the motor. At this instant the unloading valve should bleed the air.

4. If necessary, replace the bearings in the following sequence.

- Remove the unloading valve from the bracket.
- Unscrew six bolts, remove the compressor cover.
- Remove the mushroom-type device, diaphragm and disc.
- Remove the rings from the bearings.
- Lift the shaft with bearings in the body; knock out the pin.
- Unscrew with a wrench, and remove the centrifugal governor from the shaft, holding the shaft by the belt.
- Remove the belt and take the shaft with bearings out of the body for replacement.

Solenoid Valve

Every 1000 hours of the dryer operation wash and blow off the solenoid valve. For this purpose disconnect the valve from the pipe lines, then put a rubber hose on the pipe connection. During washing procedure switch on and off the supply circuit of the valve coil.

Check the valve operation on energising the coil. If the valve fails to open, wash it. If it does not open once again replace it.

Drying Chambers

The drying chambers are interchangeable. The working life of the chamber is mainly determined by the service life of the heating element. If the heating element burns out the whole drying chamber should be replaced with a new one. The chamber silica gel does not require replacement during operation as its service life considerably exceeds that of the heating element.

After replacement, the newly installed chamber must operate a complete

twenty-four hour cycle.

Temperature Relay

The relay is housed in a case. When mounting it in the case never apply great force; it is quite enough if the relay does not spontaneously move in the case during the dryer operation.

Filter

If the filter is clogged and a decreased amount of air passes through the drying chambers replace the filter strainer, for which purpose unscrew the nut holding the strainer and remove the strainer.

When assembling the filter put on a new packing washer and coat the threads with sealing paste.

Pressure Governor

If the pressure governor leaks or does not maintain a stable pressure, overhaul it and replace the rubber disc and then set the required pressure.

Needle Valve

The needle valve (governor DEW POINT) does not require special care as a valve is employed in it in place of gland packing.

Moisture Indicator

After the dryer has worked about a year check the indicator silica gel for colour changing by forcing damp air through it. If the colour does not change replace the silica gel.

Time Relay

If the correct sequence of operation is upset in the air dryer, check the time relay, i.e. setting of cams on the shaft in accordance with the proper switching sequence of the contact plates.

If the cams are set correctly, then rotating the shaft from position 0 to 7 (according to the scale) causes the first, second and third contact plates to close. In position 7 the first and second contact plates are opened; the third plate remains closed as far as position 12 at which it opens, whilst the fourth and sixth plates close; in position 19 the fifth and sixth contact plates open, whereas the fourth remains closed as far as

position 24 (or 0). When the shaft is further rotated the cycle is repeated.

Rotation should be smooth without jamming. The worm should properly engage the worm gear.

Boosting Cabin Lighting Battery from Rectifier WSA-10

The cabin storage battery is boosted by the rectifier, type WSA-10, (Fig. 258) supplied together with the power unit, type APG-15. To boost the storage battery, proceed as follows:

1. Remove the rectifier, type WSA-10, from the power unit and bring it to the station.

2. Open panels A and B of the rectifier.

3. Connect the rectifier to the station power line, 220 V, for which purpose bridge the second and fourth contacts on panel A (both bridges should be placed in parallel).

4. Bridge the first and second contacts with the fourth and fifth contacts on panel B. This position ensures boosting of the storage battery by voltage 6 V and current of 7A.

5. Disconnect the cable with spring clips from panel B and use instead cable No. 33 with a plug that comes with the set of spare parts, tools and accessories.

6. Set rotary switch BATTERY - POWER UNIT located on the lighting board of the cabin to position POWER UNIT.

7. Plug the rectifier into the 220 V socket situated on the control cabinet.

8. Determine the polarity of the rectified voltage and battery voltage across the socket located under the cabin window near the control cabinet, using instrument AVO-5M.

9. Plug cable No. 33, observing the polarity, into the storage battery socket so that "+" of the rectifier is connected with "+" of the battery. The ammeter located on panel B of rectifier WSA-10 should read 6 to 8 A at the beginning of boosting and then gradually drop in the course of charging. The battery is considered to be charged when the rectifier current (as

measured by the instrument) is about zero.

10. Disconnect the rectifier from the storage battery and then from the 220 V power line.

11. Disconnect cable No. 33 from the rectifier and place it in the spares set case.

12. Connect the removed cable with spring clips to the rectifier.

13. Close panels A and B of the rectifier.

14. Secure the rectifier on the power unit.

15. Check the voltage of the charged storage battery across the terminals of the socket, using instrument AVO-5M; it should be of the order of 7.8 V.

When lighting the cabin from the battery, switch on not more than two lamps at a time. The battery ensures six-hour supply of the two lamps and twelve- or thirteen-hour supply of one lamp. After that the battery should be boosted again.

Every day check the battery voltage; it should be not lower than 5.5 V. IF THE BATTERY VOLTAGE DROPS TO 5.5 V BOOST THE BATTERY AT ONCE. Discharging of the battery to lower than the above voltage or letting it stay run down for a long period is harmful (because of deposition of poorly soluble salts on the electrodes).

Not less than once every three months send the storage battery to a charging station for preventive servicing, washing, changing of electrolyte and main charging.

/ Table of Lubrication ...

Table of Lubrication of Station Mechanisms

Preparation for lubrication	Lubrication sequence	Grade of grease or substitute	Period of lubrication	Notes
	Antenna Control Unit			
Remove the unit from the panel and place it on the table. Remove the unit plating. Clean the unit mechanisms of dust, old grease and wipe them thoroughly.	Lubricate accessible bearings with the aid of a hard brush. Slightly lubricate the teeth of accessible gears by means of a soft brush.	CIATIM-201 GOI-54 CIATIM-201 GOI-54	Every three months Every month	1. If the station operates in damp weather, dusty atmosphere(regions of chemical plants, coal mines, etc.) inspect the unit mechanisms at least twice a month and lubricate whenever necessary. 2. Wash and lubricate closed bearings if the repair involves dismantling of the unit mechanism.
	Range Mechanism			
Remove the unit from the panel and place it on the table. Remove the plating and cover of the distributing mechanism.	Lubricate all accessible bearings with a bard brush	CIATIM-201 GOI-54	Every three months	1. If the station operates in damp weather, dusty atmosphere(regions of chemical plants, coal mines, etc.) inspect the unit mechanisms at least twice a month and lubricate whenever necessary. ....

1	2	3	4	5
Clean the mechanisms of dust and old grease and wipe them thoroughly.	Slightly lubricate the teeth of accessible gears by means of a soft brush.	CIATIM-201 GOI-54	Every three months	2. Wash and lubricate the bearings and mechanisms enclosed in the housing of the main distributing shaft if repair involves dismantling of the unit mechanism.
		Plan-Position Indicator Unit		
Remove the unit from the panel and place it on the table. Clean the mechanism of dust and wipe it thoroughly.	Slightly lubricate the idle gear accessible bearing with the help of a soft brush.	CIATIM-201	Every three months	1. If the station operates in damp weather, dusty atmosphere(regions of chemical plants, coal mines, etc.) inspect the unit mechanisms at least twice a month and lubricate whenever necessary. 2. Wash and lubricate the remaining bearings when repair involves dismantling of the unit mechanism.
		Antenna Pedestal. Azimuth Drive Mechanism (Fig.247, a)		
Remove the pedestal housing. Clean the azimuth drive output gear, the pedestal azimuthal gear and all gears of the selsyn drive of dust and old grease and wipe them	Pour oil through a hole in the azimuth drive housing until oil appears in the hole of reference plug 3. Tighten the reference and filling plugs.	Spindle oil, grade AU	Every six months	1. If the station operates in damp weather, dusty atmosphere(regions of chemical plant, coal mines, etc.) inspect the

1	2	3	4	5
				mechanisms of units at least twice a month and lubricate whenever necessary.
	Lubricate the azimuth drive output gear and the pedestal azimuth gear with a hard brush.	CIATIM-201 GOI-54	Every three months	
Unscrew drain plug 2 in the azimuth drive housing and drain the oil into a 3-litre vessel prepared beforehand. Screw in the drain plugs, screw out the reference and filling plugs.	Slightly lubricate the teeth of all gears of the selsyn drive with the aid of a hard brush.	CIATIM-201 GOI-54	Every three months	
	Mechanisms of Elevation Drives (Fig. 248, b)			
Set the antenna pedestal in elevation by 15-00 manually by the bracket. Unscrew drain plug 1 in the elevation drive housing and drain oil into a 3 litre vessel. Set the antenna pedestal in elevation by 0-00.	Pour in 0.8 to 1 lit. of oil through the drain plug hole in the elevation drive housing. Screw in and tighten the drain plug.	Spindle oil grade AU	Every six months	
Clean the output gear of the elevation drive, the sector gear and the spring with the cam clutch (Fig.248,b) of dust and old grease and then wash and wipe them. For this purpose, proceed as follows: - measure distance L which must correspond to the value adjusted at the Manufacturing plant (34.5 mm);	Lubricate the teeth of the elevation drive output gear and of the sector gear as well as the clutch with a hard brush.	CIATIM-201 GOI-54	Every week	If the station operates under dusty atmosphere conditions inspect the mechanisms daily and clean and lubricate them whenever necessary.

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1	2	3	4	5
- take out locking pin 9 and remove nut 8, washer 7, spring 6, coupling 5 and gear 4; - clean the removed parts and the end of the mechanism output shaft which protrudes from the reduction gear case and wash them in petrol. Take special care in cleaning and washing the splines of the shaft and gear; - assemble the cam clutch. When assembling keep value of L strictly within the limits (34.5 mm) since during its increase the station will not operate when wind velocity approaches 25 m/sec. In some cases when the antenna fails at wind velocity of about 25 m/sec. value of L may be somewhat reduced but it should not be less than 30 mm.				
Unscrew the screws holding the round cap on the inside of the elevation selsyn drive housing. Remove the cap.	Lubricate the teeth of the elevation selsyn drive gears with a hard brush, the antenna pedestal being rotated manually in azimuth by the bracket.	CIATIM-201 GOI-54	Every three months	
Through the opening in the housing clean the gears of the elevation selsyn drive of old grease, the antenna pedestal being rotated in azimuth by the bracket.	Through the holes in the sector gear lubricate the gear behind the sector gear with the help of a hard brush, the antenna pedestal being rotated manually in elevation. Place the round cap in position.	CIATIM-201 GOI-54	Every three months	

1	2	3	4	5
	Trailer Chassis (Fig.248)			
Clean of dirt, dust and old grease and wipe thoroughly: (a) pins of front wheel steering knuckles, torsion cylinders, tow bar pivots, wheel brake expansion camshaft.	Pack grease through lubricator fittings 1, 2, 3 and 4 by means of a lubricating gun until fresh grease appears in the slots.	Solid oil GOST 1033-41	Every 500 km. of running.	Use solid oil, grade M, in summer time and grade L in winter time.
(b) turning bar knuckles	Pack grease through two lubricator fittings of the ball ends by means of a lubricating gun until fresh grease appears in the slots.	Solid oil GOST 1033-41	Every 500 km. of running	Use solid oil, grade M, in summer time and grade L in winter time.
	Oil the knuckle joints with thin oil.	Motor oil		
(c) Front and rear wheel hubs	Pack the required amount of grease through fittings 6, 7 by means of a lubricating gun.	Solid oil GOST 1033-41	Every 5400 to 6000 km. of running	Use solid oil, grade M. in summer time and grade L in winter time.
(d) Jacks	Pack the required amount of grease through lubricator fittings by means of a lubricating gun.	Solid oil GOST 1033-41	Every three or four months	Use solid oil, grade M, in summer time and grade L in winter time.
(e) Terminals of the storage battery	Coat thinly with grease by a blade tool	Solid oil GOST 1033-41 or motor oil	Every month	Use solid oil, grade M, in summer time and grade L in winter time.
	Automatic Air Dryer			
Compressor bearings	Lubricate through side windows in the compressor case	KW	Every 600 hours of operation	

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.../Chapter 8

Chapter 8

STORAGE INSTRUCTIONS

1. PREPARATION FOR STORAGE

Upon arrival of the radar station at the storage place set it up and check its operation and in addition carry out the following procedures:

1. Before preparing for storage carry out preventive inspection prescribed by the annual preventive servicing and remove any faults.

2. Switch on the station (without switching on high voltage) for continuous operation for four hours to dry out the units. During the drying procedure open all the ventilation ports. Open the station doors in summer time. After that blow off the feeder system with air from the automatic air dryer for 10 minutes (with the antenna head cap removed) and switch off the station.

3. Thoroughly clean of dirt and dust all exposed parts of the cabin having no anti-corrosive coating and all the cabin accessories and then lubricate them with an even thick layer of solid oil (GOST 3005-51).

4. Blow off the air brake system for 15 minutes, then shut and secure the air hose on the cabin towbar, shut and oil the air cock.

5. Clean the stove accessories and place them in the ashpit.

6. Remove and send the storage battery to the charging station to prepare it for storage and after that place it in the battery container.

7. Thoroughly clean all the metal parts of the antenna pedestal having no anti-corrosive coating and lubricate them with an even thick layer of solid oil. Remove the sight and place it in the case with spare parts, tools and accessories.

8. Lubricate all inner metal parts of the range mechanism unit, plan-position indicator unit, antenna control unit, having no anti-corrosive coating, thinly with an even layer of solid oil. Wipe all exposed unpainted metal parts of the units and inner unpainted components of the cabin with a soft dry cloth and lubricate.

9. Stop the tube on the high-voltage transformer Tr25-8 with a wooden plug.

10. Arrange and secure six bags with silica gel, one kilogram each, under the main control board and behind the transmitter (silica gel must be preheated at temperatures from 150 to 200°C for a period of six hours).

11. Pack up the station.

12. Cover the transmitter, main control board and automatic air dryer with canvas covers.

Note: The covers must be cleaned of dust and dirt and dried out beforehand.

13. Shut the ventilation ports and doors of the station. Coat all butts formed by the door leaves, ventilation ports, halves of the antenna dome on the outside of the cabin with a layer of green non-drying grease and carefully paste on it strips of impregnated material.

Cover the trailer with a canvas cover.

14. Protect the wheel tyres from the sun's rays by means of wicker mats or covers.

15. Uncoil and check the cables, repair any faults and then cover with talc and coil them on the drums.

2. STORAGE

The station should be stored in covered premises protecting it against the elements, on supports taking the weight off the chassis.

Twice a year in dry and warm weather open, set up, inspect, switch on the station and, if necessary, repeat the measures detailed in the present Chapter.

3. REMOVAL FROM STORAGE

When removing the station from storage, proceed as follows:

1. Remove the wicker mats or covers from the trailer wheels.

2. Remove the storage battery and send it to the charging station to prepare it for operation and charging. After that place the battery in position.

3. Remove the sealing strips from the places specified in Section I, Item 13, and, using a rag soaked in petrol, wipe off the traces of grease which was applied when preparing the station for storage.

4. Remove the trailer from the supports.

5. Withdraw the wooden plug from the tube on the transmitter high-voltage transformer Tr25-8.

6. Take the six bags with silica gel from under the main control board and from behind the transmitter and place them in the spares cases.

7. Carry out the operations under periodic inspection, laid down in Part 2, Chapter 7.

8. Before initial energising of the new station carry out operations as instructed under Chapter 7, Section 2, "Monthly Preventive Servicing", Items 1-4, 7, 13, 20, 22-25, and replace the grease coating the exposed parts of the unit mechanisms. After that switch on the station and check its tuning and operation.

Chapter 9

OPERATION OF RADAR STATION UNDER LOW AND HIGH TEMPERATURE CONDITIONS

1. OPERATION OF STATION AT LOW TEMPERATURES

The station is always ready for combat operation at low temperatures by maintaining temperatures within +10 to 25°C day and night inside the cabin. In this case the tuned station ensures determination of target co-ordinates exactly according to the Specifications.

To make the station operate normally under low temperature conditions, proceed as follows:

- seal the station.

- maintain a temperature of not less than +10°C inside the cabin.

- follow the rules for operation of the station under low temperature conditions given in the present Chapter.

- prevent ice formation on the current collector slip-rings.

The station should be sealed as follows:

- shut all ventilation ports of the station.

- set the shutters of the main control board fan to position WINTER and of the transmitter cabinet fan to a position ensuring operation in winter.

- coat all butts formed by the door leaves and ports (with the exception of the entrance door) from the outside of the cabin with a layer of green non-drying grease and paste on it strips of impregnated material.

- install the station in a heated shelter.

The station is heated by the stove. During operation the heating should be reduced and vice versa. When firing the stove, observe fire precautions. Every day switch on the station for 30 or 40 minutes to heat the equipment more uniformly. Switch on the station carefully at low temperatures.

Before energising the station during operation under low temperature conditions or at high humidity, proceed as follows:

1. Dry out the station equipment, using the main control board electric heater and the stove for several hours until moisture is fully removed, special attention being given to the transmitter. the plan-position indicator unit, the

range indicator unit, the power pack of the range and plan-position indicator systems, which operate under high voltage. When drying, open the side doors of the transmitter cabinet.

2. Blow off the antenna-feeder system with dry air after removing the cap from the antenna head.

3. Check the antenna rotation, for which purpose rotate slowly the azimuth and elevation handwheels, simultaneously watching the antenna rotation. If the antenna fails to start switch off the amplidynes and find the trouble (which may be caused by freezing of the brushes to the current collector slip-rings, heavy thickening of the grease in the reduction gear, etc.).

If the antenna begins rotating (when the handwheels are operated) gradually increase its rotation speed and turn the antenna several times in either direction in azimuth. Tilt the antenna up and down several times in elevation without knocking it against the stops.

4. To avoid ice-formation on the current collector slip-rings check their condition periodically and wipe them with a surgical tape soaked in alcohol (see Part 2, Chapter 7, Section 4).

5. The instruments or other equipment brought into the cabin (the AVO, antenna head, echo box) will sweat due to the increased cabin temperature. Therefore, wait until some drops accumulate on the surface, remove moisture with clean waste and in 10 or 15 minutes, after making sure that there is no moisture on the surface, place the instrument in position.

6. In special cases the station may be switched on without preheating, in which case proceed with care (do not switch on the main control board electric heater, and do not fire the stove). For the first two or three hours of operation the errors in determining co-ordinates may exceed the values specified in the instructions.

/2. OPERATION OF STATION .....

2. OPERATION OF STATION AT HIGH TEMPERATURES

In summer time when the ambient air temperature is high carry out the following operations:

- place the shutter of the transmitter cabinet fan to position SUMMER.
- place the shutter on the housing of the main control board and fix it in the upper position by means of a thumb screw.
- shut the ventilation port on the control panel by the movable cover.
- slide out the cover closing the ventilation port on the outside in the cabin floor, threequarters of its length.
- open the ventilation ports.
- switch on the cabin fan.
- open the magnetron compartment on the side of the modulator front panel.

After prolonged operation of the station at high temperatures it is recommended that the units of the main control board and driver be removed and their lower walls be unscrewed, allowing visual exterior inspection of the condition of the unit components.

Chapter 10

TUNING AND ADJUSTMENT OF STATION UNITS AND SYSTEMS

The present Chapter deals with the rules on control, tuning and adjustment of the station units after repairing or replacing the components and also in case the adjustments specified in Chapter 3 do not aid in tuning the units. The units are tuned and adjusted by means of the measuring instruments on the station inventory.

Cases where special equipment is used are dealt with separately; in these cases the units are tuned and adjusted by the radio technical unit in artillery workshops or by an inspection and repair workshop (KRAS).

When describing the sequence in adjusting individual systems of the station it is assumed that the systems are sound but need tuning.

The station should be tuned in the following sequence:

- the antenna positioning system during manual operation;
- the range measuring system (without the automatic range finder unit);
- the transmitting system;
- the receiving system and the station high frequency channel;
- the plan-position indicator system.

After that, tune the antenna positioning system during automatic target tracking and the automatic range finder.

In case one or another unit or system cannot be tuned and adjusted, find the cause of trouble as instructed under Part 2, Chapter 11 and consulting the key circuit diagrams.

1. ANTENNA POSITIONING SYSTEM

Tuning and adjustment of the antenna positioning system consists in tuning the system during manual tracking and during automatic target tracking, which boils down to adjustments of the azimuth and elevation tracking units, the automatic tracking unit and the reference voltage generator.

The antenna positioning system is tuned at the Manufacturing plant

by measuring gain-frequency characteristics of the station by means of the gain-frequency characteristic meter Ural 2. In this case positions of knob AMPLIFICATION (R6-8, R6-9) on the automatic tracking unit and knobs FEEDBACK (R10-24, R10-74) on the azimuth and elevation tracking unit are selected and entered in the log book.

When tuning the antenna positioning system, in case it has not undergone repairs involving replacement of the amplidynes, drive motors, reference voltage generator or changes in the circuits of the units, make sure that the knobs are set and modes of operations observed according to the log book. Otherwise tune the antenna positioning system with the help of the meter Ural 2.

Usually the system is checked, tuned and adjusted twice a year by means of the above meter Ural 2 (see Appendix 3).

Tuning the System During Antenna Manual Control

To prepare the system for tuning, apply voltage to the automatic tracking unit, for which purpose set the supply switch located on the unit front panel in position ON. In this case the pointer of instrument PLATE CURRENT located on the front panel must deflect by 13 to 19 mA. Shift function switch MODE OF OPERATION (W12-1) situated on the antenna control unit to position AUTOMATIC and switch SELSYNS on the control panel to position ON. Do not switch on the amplidynes and the reference voltage generator. Switch on the scale lighting on the receiving selsyn unit.

Stop the azimuth selsyn drive. For this purpose remove the antenna pedestal housing from the left-hand and right-hand sections and push the handle of the stop located on the big gear of the azimuth motor drive as far as it will go. Place the housing in position and secure it with screws. Turn the switch INTERLOCKING on the panel of the antenna control unit to ON.

When tuning the system, proceed as follows:

.../1.

1. Turn the handwheels of the antenna control unit several revolutions in either direction, after which place function switch MODE OF OPERATION in position MANUAL. Set selector switch ELEVATION - AZIMUTH (W10-1) located on the front panel of the azimuth and elevation tracking unit to position AZIMUTH and then to position ELEVATION.

In either position of the selector switch both instruments FIELD CURRENT situated on the front panel of the azimuth and elevation tracking unit should read 10 to 40 mA.

Place the selector switch to position AZIMUTH by turning the azimuth handwheel clockwise. In this case the pointers of instruments FIELD CURRENT should come apart, i.e. the left-hand instrument should read low, and the right-hand one high, which testifies to the fact that the error voltage is properly phased relative to the reference voltage.

If the pointers are brought together, interchange the wires attached to terminals 1 and 3 on azimuth follow-up motor M12-3 in the antenna control unit.

After setting the selector switch to position ELEVATION turn the elevation antenna control handwheel clockwise. The pointers of instruments FIELD CURRENT should come apart.

If they do not, interchange the wires attached to terminals 1 and 3 on elevation follow-up motor M12-52 located in the antenna control unit.

2. Set a D.C. voltage of 27 to 33 V between monitoring jacks +30 V (G10-13) and EARTH (G10-3) located on the front panel of the azimuth and elevation tracking unit by turning the shaft of twin potentiometer FEEDBACK LIMITING (R10-14, R10-15).

3. Set a D.C. voltage of 31 to 37 V between monitoring jacks +34 V (G10-14) and EARTH (G10-3) by turning the shaft of potentiometer TORQUE LIMITING (R10-33) on the unit front panel.

4. Check the voltage between monitoring jacks +30 V and +34 V; it

.../should be

should be within 3.6 and 4.4 V. If this requirement is not complied with adjust the given voltage by turning the shafts of potentiometers FEEDBACK LIMITING and TORQUE LIMITING, the voltage across the jacks mentioned in Items 2 and 3 must be normal.

5. Turn the azimuth handwheel in the antenna control unit to obtain equal readings of instruments FIELD CURRENT. In this case selector switch ELEVATION-AZIMUTH must be in position AZIMUTH.

By turning the shaft of potentiometer FIELD CURRENT located to the right on the panel of the azimuth and elevation tracking unit make sure that both instruments read 25±2 mA.

6. Set selector switch ELEVATION - AZIMUTH of the instruments to position ELEVATION.

Rotate the antenna elevation control handwheel in the antenna control unit to obtain equal readings of both instruments FIELD CURRENT. Make the current values of both instruments equal to 25±2 mA by turning the shaft of potentiometer FIELD CURRENT located to the left on the panel of the azimuth and elevation tracking unit.

7. Set the knobs of potentiometers FEEDBACK located on the front panel of the azimuth and elevation tracking unit to figure 3 on the scales.

8. Switch on the azimuth and elevation amplidynes by means of magnetic starters located on the control panel.

9. Turn the antenna elevation control handwheel clockwise watching the system operation. If the system is sound:

- the antenna should rise (elevation should increase);

- the scale of the antenna elevation position indicator in the automatic tracking unit should rotate clockwise;

- the pointers of instruments FIELD CURRENT must come apart at the instant the handwheel is turned (instrument selector switch ELEVATION - AZIMUTH should be placed in position ELEVATION);

.../- the scale

- the scale of the antenna azimuth position indicator located in the automatic tracking unit should rotate clockwise;

- the pointers of instruments FIELD CURRENT should come apart at the instant the handwheel is turned (instrument selector switch ELEVATION - AZIMUTH should be placed in position AZIMUTH);

- the scale of the azimuth receiving selsyn located in the receiving selsyn unit should rotate in a clockwise direction.

11. Switch on the reference voltage generator. Turn knob AMPLIFICATION (R6-8, R6-9) on the automatic tracking unit panel as far as it will go. Set selector switch MODE OF OPERATION (W12-1) on the panel of the antenna control unit to position AUTOMATIC. In this case the antenna can spontaneously rotate in azimuth and elevation.

Stop the antenna spontaneous rotation in elevation by turning the shaft of potentiometer BALANCE (R6-62) (located on the left of the front panel of the azimuth and elevation tracking unit).

Stop the antenna spontaneous rotation in azimuth by turning the shaft of potentiometer BALANCE (R10-12) (located on the right of the front panel of the azimuth and elevation tracking unit).

12. Set function switch to position MANUAL. Set the knob of elevation potentiometer FEEDBACK (R10-74) to zero. Slightly turn the antenna control handwheel in elevation, which will result in the antenna oscillating in elevation. Turn the knob of the feedback potentiometer slowly until the antenna stops oscillating. Turn the knob by one division more in a clockwise direction.

13. Set the knob of azimuth feedback potentiometer FEEDBACK (R10-24) to zero. Slightly advance the antenna control handwheel in azimuth and if the antenna starts oscillating in azimuth, turn the knob of the feedback potentiometer slowly until the antenna stops oscillating. Turn the knob clockwise by one more division.

.../The knobs

The knobs of the azimuth and elevation amplification and feedback potentiometers are finally set when tuning the antenna positioning system during automatic target tracking (See Section 7 of the present Chapter). The knob positions are entered in the station log book.

Checking Beating and Centring of the Antenna Head

Beating occurring during the antenna head rotation change deflections of the radiation pattern from the antenna axis and can impair automatic target tracking. It is necessary to periodically check the magnitude of beating and to centre the antenna head, whenever necessary. In doing this, proceed as follows:

1. Attach an indicator to the frame (Fig. 258) of the reference voltage generator so that its probe touches the antenna head feeder near the nuts securing the polystyrene housing of the head. When the antenna head rotates the indicator reading difference should not exceed 0.1 mm. The polystyrene housing beating should not exceed 0.5 mm.

Note: In field conditions, if there is no indicator at hand, the beating may be checked in a more simple way. For this purpose, proceed as follows:

- energise the reference voltage generator;

- slightly touch the feeder of the rotating antenna head with a pencil near the nuts securing the polystyrene housing;

- de-energise the motor of the reference voltage generator and check the pencil trace on the feeder surface; if the head is centred properly the trace should occupy at least three-quarters of the circumference.

2. To centre the antenna head, proceed as follows:

- slacken clamping bolts 5 (Fig. 259) located in the flange of the reference voltage generator sleeve;

- by rotating adjusting (retaining) screws 4 centre the antenna head, checking its position against the indicator or using the above simplified method;

- tighten the clamping bolts;

.../ - check once more

- check once more the centring of the antenna head and repeat the adjustment, if necessary.

2. RANGE MEASURING SYSTEM

When tuning the range measuring system connect the unit being tuned to the main control board through connecting cables, if necessary.

Remark: In the stations of earlier design, sweeps of the coarse and fine range indicators become distorted when the range unit, the range indicator unit, and the very-narrow gate unit are connected to the main control board with the aid of extension cables. This must be remembered when adjusting the system.

In some cases in order to gain access to the place of adjustment and to sockets remove the unit located above the unit being tuned.

It will be shown later how to proceed in each particular case. But it is well to remember that each time before removing the unit from the main control board the system must be de-energised.

When tuning the system switch on the range system supply. Allow the unit to warm up for at least 15 min. Measure the stabilized voltage by the instrument situated on the panel of the power pack of the range measuring and plan-position indicator systems, (in the stations of earlier design, selector switch MEASUREMENT should be set in position "270 V.").
If the instrument reads other than 270 V turn the shaft of potentiometer STABILIZED VOLTAGE (R5-33) to adjust the voltage.

The range measuring system should be adjusted in the sequence given below.

Adjusting the Fine Range Tube Sweep

When adjusting the sweep on the fine range indicator use controls designated SWEEP, 2 km., located on the front panel of the range unit. In doing this, proceed as follows:

1. Brighten the fine range sweep, turning knob STROBE WIDTH (R8-88) to the left as far as it will go. Operate knobs FOCUS (R3-16) and INTENSITY (R3-13) located on the panel of the range indicator unit and

obtain a definite sweep trace.

2. Operate shaft GENERATOR (C8-54) to obtain maximum size of the ring. If the diameter of the ring is too big (goes outside the screen) reduce it by rotating shaft DIAMETER (R8-36).

3. Operate shafts PHASE (C8-58) and BALANCE (R8-38) to obtain the circular sweep. Both shafts are interconnected and they should be used together by turning them alternately.

4. If a correct circle cannot be obtained by these adjustments, make the necessary adjustments by transformer Tr8-1 of the range unit and transformers Tr3-2 and Tr3-3 of the range indicator unit. To do this, proceed as follows:

- connect the range and range indicator units to the main control board through connecting cables;

- switch on the range measuring system supply and allow the units to warm up;

- set the shaft of trimmer capacitor GENERATOR in the mid-position.

Note: The unit panels, in which the trimmer capacitors are installed without mechanical stops, are provided with white enamel marks. They indicate the position of the capacitor shaft slot corresponding to the maximum value of its capacitance. This position is equivalent to the mechanical stop.

- obtain the maximum sweep diameter by adjusting the primary winding of transformer Tr8-1 (upper adjusting screw);

- set the shaft of trimmer capacitor PHASE in the mid-position;

- turn the shaft of potentiometer BALANCE first clockwise as far as it will go, then counter-clockwise through an angle of 60 -90°;

- obtain the correct circular sweep form on the screen of the fine range indicator by adjusting the secondary winding of transformer Tr8-1 (lower adjusting screw) and transformers Tr3-2 and Tr3-3.

After that, replace the units.

5. By turning shafts CENTRING (R3-26, R3-27) and DIAMETER (R8-36)

.../match

match the circular sweep with the reference circle plotted on the transparent overlay on the indicator screen. Check the sweep form again and, if necessary, repeat adjustment procedure mentioned in Item 3.

6. Set the circular sweep diameter to approximately 50 mm by using shaft DIAMETER.

Adjusting the Multivibrators

Remove the automatic range finder from the main control board. Switch on the system and allow the units to warm up. Brighten the range indicator tube by turning the shafts STROBE WIDTH and GATING WIDTH (R8-77) to their extreme counter-clockwise positions. Adjust intensity and focusing of the sweeps on both indicators. Connect pilot cable No. 2 to connector CENTRAL ELECTRODE on the panel of the range and very-narrow gate indicator unit. Shift selector switch OPERATION - CHECK located on the panel of this unit to position CHECK.

Multivibrator 15 Kc/s

Plug pilot cable in jack G8-1 located on the chassis of the range unit. Turn shaft 15 Kc/s of trimmer capacitor C8-6 (on the range unit panel) to obtain a five-turn spiral on the screen of the fine range tube (jack G8-1, Fig. 260). This display should be stable when turning the shaft within certain limits. Set the shaft mid-way between the extreme positions corresponding to a stable display. If the stable display is difficult to obtain, change the setting of shaft 3.75 Kc/s and make adjustments again.

With multivibrator 3.75 Kc/s adjusted (See below) four pips should be visible on the sweep of the coarse range tube.

Multivibrator 3.75 Kc/s

Plug pilot cable in jack G8-10 located on the chassis of range unit. By turning shaft 3.75 Kc/s of potentiometer R8-12 make twenty pips appear on the screen of the coarse range tube (jack G8-1, Fig. 260). This

.../display

display should be stable when turning shaft 3.75 Kc/s within samll limits. Place the shaft mid-way between the extreme positions corresponding to a stable display. If the stable display is difficult to obtain, charge the setting of shaft 1.875 Kc/s and make adjustments once again.

Multivibrator 1.875 Kc/s

Plug the pilot cable in jack G8-4 located on the panel of the range unit. By turning shaft 1.875 Kc/s of potentiometer R8-16 make a two-turn spiral appear on the screen of the coarse range tube (jack G8-4, Fig. 260). This display should be stable when turning shaft 1.875 Kc/s within certain limits. Place the shaft mid-way between the extreme positions which correspond to a stable display.

Having adjusted multivibrator 1.875 Kc/s, re-check the oscillograms taken from jacks G8-1, G8-10 and G8-4 and repeat adjustments of the multivibrators, if necessary.

Adjusting the Coarse Range Indicator Sweep

When adjusting the sweep of the coarse range indicator use controls marked SWEEP, 40 km., located on the front panel of the range unit.

Adjusting, in the following sequence:

1. Turn shaft GATING WIDTH to its maximum counter-wise position and adjust intensity and focusing of the sweep.

2. Operate shafts PHASE (C8-65) and BALANCE (R8-19) to obtain the circular sweep.

If a correct circuit cannot be obtained by these adjustments make the necessary adjustments by operating transformer Tr8-2 of the range unit and transformers Tr3-4 and Tr3-5 of the range indicator unit, in the following sequence:

- connect the range indicator unit and range unit to the main control board with the help of connecting cables;

- switch on the system and allow the units to warm up;

.../- place

- place shaft PHASE of the trimmer capacitor to the mid-position;

- turn the shaft of potentiometer BALANCE first to the maximum clockwise position and then counter-clockwise through an angle of 60 to 90°.

- turn the adjusting screws of transformers Tr8-2, Tr3-4 and Tr3-5 to obtain the correct sweep form and maximum circle diameter;

- replace the units in the control board and repeat the adjustment procedure mentioned in Item 2, if necessary.

3. Match the centre of the circular sweep with that of the screen by operating adjusting screw CENTRING (R3-31, R3-32).

4. Set the sweep diameter to approximately 50 mm by means of adjusting screw DIAMETER (R8-21).

Adjusting the Trigger Pulse Delay

To adjust the trigger pulse time delay, proceed as follows:

1. Turn adjusting screw GATING WIDTH counter-clockwise as far as it will go and adjust the sweep intensity and focusing.

2. Set the shaft of potentiometer TRIGGER PULSE DELAY (R6-27) in the extreme left position.

3. Plug the pilot cable in jack G8-9 located on the chassis of the range unit. The screen of the coarse range indicator will display an inward sweep pip, formed by strobe pulse. A small peak formed by a trigger pulse (jack G8-9, Fig. 260) is noted on the pip top.

4. Turn the shaft of potentiometer TRIGGER PULSE DELAY slowly in a clockwise direction. The pip on the sweep of the coarse range indicator will move relative to the peak of the trigger pulse oscillator until the peak is out of the pip. When turning the shaft further a second, third, etc. peaks from the trigger oscillator pulses will be within the pip.

Set the shaft TRIGGER PULSE DELAY in a position at which the third peak will occupy a steady position in the middle of the pip.

.../Adjusting the

Adjusting the Linearity of Strobe Pulse Shift

These adjustments should be made in cases where the electronic markers do not follow the strobe pulse when the range is changed within 0 and 40 km., on the scale. In doing this, proceed as follows:

1. Turn adjusting screw GATING WIDTH on the range unit panel fully counter-clockwise. Turn knob STROBE WIDTH to obtain the strobe width of 100 to 1500 m. on the screen of the fine range tube.

Adjust the sweep intensity and focusing.

2. By varying the range within 0 and 40 km., by means of the handwheel check the stability of the strobe pulse delay circuit operation. The strobe pulse while shifting should not jump, split or vanish.

3. Feed the trigger pulse to the central electrodes of the range indicators by plugging the pilot cable in jack G8-12 located on the panel of the range unit.

4. Set the range mechanism scales to zero. Set the shaft BEGINNING (of potentiometer R4-23 STROBE CONTROL) on the panel of the range mechanism unit so that the trigger pulse is seen on the screen of the fine range and the high-lighted sweep section is located in symmetry with the pulse.

5. Set the range mechanism scales to 40 km. Set shaft END (of potentiometer R4-25 STROBE CONTROL) so that the strobe brightening of the coarse range indicator sweep is located in symmetry with the trigger pulse.

6. Repeat operations mentioned under Points 4 and 5 to obtain symmetrical location of the strobe pulse relative to the trigger pulse when setting the range mechanism scales to 0 and 40 km.

7. After setting zero range reading (See Section 11 of the present Chapter) check the linearity of the strobe-pulse shift as instructed under point 5, Section 2, Chapter 3, Part 2.

Adjusting the Blocking Oscillators

Adjustment of the blocking oscillators is required to obtain a stable

.../electronic

electronic marker on the fine range indicator. In doing this, proceed as follows:

1. Plug the pilot cable in jack G3-3 on the chassis of the range indicator after removing the range channel amplifier unit from the main control board.

2. Turn knob STROBE WIDTH to obtain the full period of the sweep highlighted on the fine range tube.

3. Set shaft BIAS (R5-18) on the panel of the power pack of the range measuring and plan-position indicator system in the extreme right position. Slowly turn shaft BIAS counter-clockwise to obtain electronic markers and a very-narrow gate pip presented as an inward radial deflection (jack G3-3, Fig. 260).

4. Note the extreme positions of the potentiometer shaft at which the pip and electronic marker on the fine range tube sweep become unstable and place them in the mid-position.

Adjusting the Electronic Marker Linearity

To provide normal operation of the station, the non-linearity of the electronic marker follow-up of the fine scale turn of the range mechanism should not be greater than ±20 m. If the marker non-linearity exceeds ±20 m. adjust the phase-shifter bridge of the range mechanism unit.

The bridge should be adjusted by the carefully adjusted sweep as follows:

1. By turning the shaft of potentiometer BALANCE-2 (R4-10) on the panel of the range mechanism unit and the range handwheel within 2 km. (as measured by the scale) determine:

- the positions of the range mechanism fine scale in which adjusting screw BALANCE-2 causes minimum displacement of the elctronic marker spots. In these positions adjusting screw BALANCE-3 (R4-11) should cause minimum shift of the marker spots as well. There must be two such positions.

.../One of them

SECRET

One of them is taken for the initial position (position I);

- an approximate position of the range mechanism fine scale in which adjusting screw BALANCE-2 causes maximum shift of the electronic marker spots. There should be one such position (position II).

2. Apply voltage from jack OUTPUT VOLTAGE (G4-6) located on the panel of the range mechanism unit to instrument AVO-5 (scale for 12 V A.C.) or the oscillograph and measure its magnitude for position I of the mechanism.

3. Turn the fine range scale by 1000 m. away from position I and measure the voltage magnitude in this position of the mechanism (position III).

If the voltage value measured in position III differs from that measured in position I turn the shaft of potentiometer BALANCE-1 (R4-7) located on the panel of the range mechanism unit to change the value by half of their difference.

4. Changing position I for III several times make sure that the values of the sinusoidal voltages are equal in both positions. After that disconnect the device.

5. Set the range mechanism fine scale to position I. Align the radial notch of the check disc with the end of the first spot of the electronic marker.

6. Set the range mechanism fine scale to position III. Note the distance between the end of the marker first spot and the disc notch and by rotating shaft PHASE (C4-7) on the range mechanism panel turn the marker by the half of this distance towards the notch.

7. Repeat adjustment as instructed under Points 5 and 6. Make sure that the end of the first spot of the elctronic marker is brought in line with the check disc notches when setting the range mechanism fine scale in positions I and III.

8. Turn the range mechanism fine scale by 500 m. from position I

.../(position II)

(position II) and by rotating shaft BALANCE-2 on the panel of the range mechanism unit align the end of first spot of the eletronic marker with the check disc notch.

9. Turn the range mechanism fine scale in the other direction by 500 m. relative to position I (position IV) and by rotating shaft BALANCE-3 align the end of the first spot of the eletronic marker with the check disc notch.

10. Repeat adjustments specified in Item 7, and then in Items 8 and 9 and make sure setting of the range mechanism fine scale in positions I, II, III and IV brings the end of the electronic marker first spot in line with the check disc notches.

It should be borne in mind that all adjustments influence each other. Therefore, if the desired adjustment under Item 10 is difficult to perform repeat the adjustment procedure once more and then a third time, if necessary.

11. After the phase shifter bridge has been adjusted check the linearity with which the electronic marker follows up the turn of the fine scale of the range mechanism as instructed under Part 2, Chapter 3, Section 2, Item 3.

Adjusting the Indicator Gating Circuits

To adjust the circuits, proceed as follows:

1. Reduce brightness until the sweeps have disappeared on the screens of both indicators.

2. Adjust the strobe width by turning knob STROBE WIDTH (R8-88) located on the range unit panel so that the high-lighted section of the fine range indicator sweep is 1000 to 1500 m. (as measured on the scale).

3. Adjust the gating width by turning knob GATING WIDTH (R8-77) so that the brightened section of the sweep forms almost a complete circle on the screen of the coarse range indicator. A small gap must be provided

.../between

between the ends of the brightened part.

3. TRANSMITTING SYSTEM

The transmitting system is checked by means of an echo box (See Section 5 of the present Chapter). If the magnetron is found to be functioning abnormally it should be replaced.

Magnetron Replacement

When installing a new magnetron special care should be taken not to damage the high-frequency output, to protect the magnet poles from knocks and contacts which may cause the demagnetisation of the magnets.

Remove the magnetron, in the following sequence:

1. De-energise the transmitter.

2. Open the front and side doors of the transmitter located close to the magnetron oscillator.

3. Without unscrewing the magnetron union nut separate the joint in the transmitter coupler (having unscrewed four fastening screws).

4. Remove the nozzle of the magnetron cooling fan by slackening first two thumb screws.

5. Remove the plugs from the magnetron heater jacks.

6. Taking hold of the magnetron unscrew three thumb screws securing the magnetron plate to the magnet.

7. Remove the magnetron with plate.

8. Unscrew the screws fastening the magnetron to the plate and remove the plate.

9. Remove the housing, having unscrewed the union nut.

10. Take the rubber washer out of the circular recess near the high-frequency output of the magnetron.

11. Put a protective cylinder on the magnetron high-frequency output.

Replace the magnetron in the following sequence:

1. Remove the protective cylinder from the high-frequency output.

.../2.

2. Insert the rubber washer in the circular recess near the high-frequency output.

3. Connect the feeder to the magnetron by screwing on the union nuts.

4. Fix the magnetron to the magnetron plate by screws.

5. Place the magnetron between the magnet poles so that the high-frequency output enters the resilient contact of the transmitter coupler.

6. Tighten the three thumb screws holding the magnetron plate.

7. Connect the transmitter with the coupler by means of four screws.

8. Insert the plugs in the magnetron heater jacks so that the plug painted red (connected to a high-voltage metal busbar) enters the upper magnetron heater jack marked with letter K (cathode).

9. Place the nozzle of the magnetron cooling fan in position by fixing it with the aid of two thumb screws.

10. Shut the side door of the transmitter cabinet.

Magnetron Pre-Ageing

A new magnetron or one which has not been used for two or more weeks should be pre-aged prior to actual operation in the following sequence:

1. Energise the transmitting system as instructed under Part 2, Chapter 2.

2. Raise high voltage to a value at which the magnetron current measured by instrument MAGNETRON CURRENT equals 7 to 10 mA and wait for 1 or 2 min. In this case the instrument readings should be stable.

3. Raise high voltage to a value at which the magnetron current is 14 to 17 mA and wait for 1 or 2 min. until the readings of instrument MAGNETRON CURRENT are stable.

4. Raise high voltage to a value at which instrument MAGNETRON CURRENT reads 21 to 23 mA and wait for 2 or 3 min. until the instrument readings are stable.

When raising high voltage make sure that the H.V. rectifier voltage

.../does not

does not exceed 22 or 23 kV with the magnetron current reading 21 to 23 mA.

5. Having set the optimum conditions, switch high voltage on and off four or five times, each time keeping the magnetron under high voltage for 3 to 5 seconds.

Controlling the Magnetron Magnetic Field

The magnetron magnetic field is controlled by changing the air gap between the magnet poles which is obtained by rotating the control knob.

With the knob rotated clockwise, the instrument MAGNETRON CURRENT will read low and vice versa.

Control the magnetic field so that the magnetron current (as measured by instrument MAGNETRON CURRENT) is 21 to 23 mA at a voltage of 22 kV. See that the gap between the magnetron and the magnet poles is not less than 1 mm on each side.

Selection of Magnetron

The magnetron in the station set of spare parts is selected at the Manufacturing Plant; thus they are selected only when bringing the set of spare parts up to establishment.

A properly selected magnetron operating at the station must comply with the following requirements (with the transmitter system operating under normal conditions and station high-voltage channel tuned):

1. The value of maximum deflection of the echo box indicator pointer should be at least 60 microA (the crystal in the echo box is assumed to be sound).

2. The ringing time value measured in accordance with the instructions given under Item 5 of the present Chapter should be close to the value entered in the station log book.

3. The pattern of distant objects on the screen of the plan-position indicator should not appreciably differ in details and definition from that obtained when the station operates on a magnetron taken from the set of

.../spare parts.

spare parts.

4. The drift in azimuth of the bearing to the landmark when the mains voltage of 110 V changes by ±2.5 V should not exceed 0-01 (selector switch MANUAL - AFC on the I.F. pre-amplifier unit must be set in position AFC).

Operation on Two Modulator Valves

Should the necessity arise the station can be operated when the modulator uses two valves GMI-30. In this case because of a decrease of the load current flowing through the secondary winding of transformer Tr25-1, the heater voltage of the modulator valves will rise to 8.5 V without any switchings in the supply circuit of the transformer primary winding, which places valves GMI-30 under increased potential, thereby ensuring normal magnetron operation.

Operating Characteristics of Relays

Relay P25-3 should operate at a voltage of -1400 V of the modulator valve bias rectifier. This relay is sent out adjusted for the pick-up current of 20 mA and does not require additional adjustments during operation.

Relay R25-6 should operate with a time delay of 45 sec.

Relay R25-4 is adjusted to a current of 40 mA and operates when the +4000-volt rectifier is overloaded.

Relay R25-5 is adjusted to a current of 80 mA and operates when the high-voltage rectifier is overloaded.

The value of the pick-up current of relays P25-4 and P25-5 is regulated by shifting the clip of the variable wire-wound resistor located under the relay cover. Each relay has two clips which are installed at the factory. Their setting corresponds to pick-up currents of 40 and 80 mA respectively.

Depending upon the purpose of the relay (for overload protection of the +4000-volt rectifier or high-voltage rectifier) use is made of the

.../clip

clip whose setting corresponds to the required pick-up current of the relay.

Relay R25-8 is adjusted to a pick-up current not exceeding 10 mA.

4. RECEIVING SYSTEM

Checking and Setting the System Performance

Setting the +120-volt stabilized voltage

Remove the amplifier unit of the automatic tracking channel from the main control board and connect it to the board by means of connecting cables. Place jumper STROBE +120 V (W1-3) located on the unit chassis to position 120 V. Turn the 120 V potentiometer shaft (R1-54) to set 120 V across jack +120 V (W1-2).

Setting the output voltage of automatic gain control stage

Set the output voltage of the A.G.C. stage at zero, which corresponds to the receiver maximum amplification. To set this voltage, proceed as follows:

1. Extract valve V1-1.

2. Set selector switch MODE OF OPERATION (W12-1) located on the antenna control unit to position MANUAL.

3. Turn knobs AMPLIFICATION (R1-44, R7-99), on the amplifier units of the automatic tracking channel and automatic range finder to the extreme clockwise position.

4. Set the shaft of potentiometer A.G.C. SETTING (R1-42), located on the amplifier unit chassis of the automatic tracking channel so that the voltage between jack 4 of valve V1-1 and chassis measured by instrument AVO-5 (3 V scale) equals zero.

After setting the above voltages place jumper STROBE +120 V in position STROBE and insert the unit in the main control board.

Setting the -250-volt stabilized voltage

Turn the shaft of potentiometer R22-50 RESONATOR VOLTAGE SETTING located on the chassis of the I.F. preamplifier unit to set a voltage of

.../-250 V

-250 V between jack - 250 V (G22-2) and chassis.

Checking the phantastron operation

Set selector switch AFC - MANUAL (W22-4) located on the I.F. preamplifier unit to position AFC. When the phantastron (V22-7), operates normally the pointer of instrument CRYSTAL CURRENTS should make not more than 3 to 5 kicks per second.

Note: When checking make sure that transmitter high voltage is off.

Setting the range-channel amplification

The noise level on the screens of the range indicators can give an idea of the range-channel amplification of the receiving system.

The normal noise level on the screen of the coarse range indicator must be 2 to 3 mm with the heterodyne energised and signal mixer crystal current of 0.2 to 0.6 mA.

With the heterodyne off, the noise amplitude may be reduced.

The range-channel amplification is controlled by the shaft of potentiometer NOISE LEVEL SETTING (R2-3) located on the front panel of the range-channel amplifier unit. In this case turn knobs AMPLIFICATION on the amplifier units of the automatic tracking channel and automatic range finder to the extreme clockwise position. Turn the antenna so that the ground-echo intensity on the indicator is at minimum.

Checking the operation of A.G.C. system

Check the operation of the system as instructed under Part 2, Chapter 3, Section 2, Item 7.

Setting the automatic tracking channel amplification

Set the automatic tracking channel amplification according to instructions given in Section 7 of the present Chapter.

The heterodyne frequency must be controlled automatically, therefore during combat operation selector switch AFC - MANUAL should be placed in position AFC. Manual frequency control should be resorted to only in

.../case

case of damage to the AFC system.

Note: Make the checks listed under sub-section "Checking and setting the system performance" periodically, whenever necessary.

Tuning the Receiving System

The present Section is concerned with the methods of checking, tuning and adjustment of the receiving system elements.

When tuning, proceed in the following sequence:

1. Tune the heterodyne to the operating frequency, for which purpose:

- Set selector switch AFC - MANUAL to position MANUAL;

- Set adjusting screw KLYSTRON FREQUENCY in the mid-position;

- Couple the echo box to connector marked TO ECHO BOX located on the front panel of the I.F. preamplifier unit;

- Shift knob REPELLER VOLTAGE (R22-56) to position 10-13;

- Switch on the unit supply.

By turning the shaft of potentiometer ZONE SELECTION (R22-59) and tuning plug of the klystron resonant cavity, tune the klystron by the echo box to a frequency 30 Mc/s higher than that of the magnetron as instructed under Section 5 of the present Chapter. When tuning the klystron to a frequency lower than that of the magnetron the automatic frequency control will not operate.

After tuning has been done the tuning plugs should be tightened with locking nuts and coupling loops installed vertically.

Note: a) When operating with magnetron MI-18 tune the klystron resonant cavity by the echo box to the magnetron frequency to obtain maximum ringing.

b) Unscrewing of the tuning plugs of the klystron resonant cavity (increase of cavity) results in a decrease of frequency whilst screwing in, in an increase of the oscillator frequency.

d) Set the operating frequency so that the instrument situated on the front panel of the I.F. preamplifier unit, (with selector switch CRYSTAL CURRENTS in position AFC) reads maximum (coupling with the heterodyne is selected). This shows operation on the medium frequency of the klystron electron tuning range ....
[one page missing]...

.../........

.... increases, in the opposite direction - decreases.

(2) Change the AFC channel amplification by turning the shaft of potentiometer AFC AMPLIFICATION (W22-65) located on the chassis of the I.F. preamplifier unit.

(3) Choose the value of the AFC mixer crystal current. If in this case the requirements of Points a, b, c, d, are not complied with, check the cross-over (zero) frequency of the AFC channel discriminator and resonance frequency of the I.F. amplifier channels by means of signal generator SG-1 (See "Tuning the Receiving System by Means of Signal Generator" given in the present Section).

8. Check the stability of the AFC operation. For this purpose after noting the position of knob ZONE SELECTION:

(a) Change slightly the klystron frequency by the knob of potentiometer ZONE SELECTION and make sure that the ground-echo pattern on the screen of the plan-position indicator tube and amplitude of pulses on the screen of the range indicators do not change.

(b) Place potentiometer ZONE SELECTION (R22-59) in the initial position and rotate the antenna in azimuth within 60-00; in this case the signal crystal current fluctuations should not exceed ±0.1 mA.

Note: Sharp current fluctuations, observed when the antenna crosses the direction to a near-by landmark are normal if they do not entail failure of A.F.C.

9. Measure the ringing time as instructed under Section 5 of the present Chapter. Enter the value obtained in the Log Book to compare it with the results of the next measurements.

Tuning the Receiving System by Echo Signal

To tune the receiving system by the signal returned from a local object, proceed as follows:

1. Switch on the station.

2. Shift selector switch AFC - MANUAL situated on the I.F. preamplifier unit to position MANUAL.

.../3.

3. Turn knobs AMPLIFICATION on the automatic tracking channel amplifier and automatic range finder units to the extreme clockwise position.

4. Shift selector switch MODE OF OPERATION (W12-1) to position MANUAL.

5. Point the antenna to a landmark located within 1 and 10 km.

6. Choose the length of the line being tuned so that the crystal current is 0.2 to 0.6 at minimum coupling between the mixer and oscillator.

Operate knob KLYSTRON FREQUENCY to adjust the klystron by the maximum of the echo pulse on the range indicators. Use knob AMPLIFICATION (located on the automatic tracking channel amplifier unit) to decrease the receiver amplification to a value at which the echo signal will not be saturated.

7. Adjust the T.R. cell by turning the cores until a maximum pulse is obtained on the screen of the range indicator. Lock the cores so as not to disturb tuning.

Note: Unscrewing the cores (increase of the T.R. cell volume) corresponds to a decrease of resonance frequency and vice versa.

If it is found that the receiving system sensitivity worsens and the ground-echo pattern changes, check the elements of the high-frequency channel.

The receiving system sensitivity may be reduced for the following reasons:

- The discharger fails to protect the crystal detector, which results in overloading of the detector by the direct pulse power penetrating into the mixer and reducing the sensitivity;

- The T.R. cell caps do not fit tight to the discharger discs;

- There is carbon deposit in the loop coupling the feeder line with the T.R. cell;

- Poor contact between the central movable and fixed conductors of the tuned sector of the line;

- Poor contact between the crystal detector holder and the mixer

.../connector

connector contact star and between the crystal and the inner conductor of the feeder line and the T.R. cell;

- The crystal detector has low sensitivity.

Replacement and Selection of Crystal

The features characterising the malfunction of the signal mixer crystal are as follows:

- Reduction of the receiver system sensitivity at its normal tuning;

- Appreciable rise of the noise level on the range indicators when the oscillator is switched on;

- Appreciable drop of the crystal current as compared with the current at previous connections and failure to obtain the normal current value by means of available tuning controls (the same is true also for the AFC mixer crystal).

On finding out the above symptoms replace the crystal.

Before installing the crystal in the mixer measure its forward and reverse resistances by crystal detector meter IKD-1. The forward resistance should be from 350 to 500 ohms, the reverse resistance - not less than 5 kilohms.

When the crystal is operating keep it free from knocks, heavy jolting and dirt.

When replacing the crystal, proceed as follows:

1. Switch off high voltage of the transmitting system.

2. Remove the adapter connector from the mixer.

3. Take the crystal gently out of the lead holder and screw a new crystal in the threaded holes of the crystal holder, seeing that the crystal is constantly shorted by the fingers.

4. Insert the crystal in the mixer. In this case hold the crystal with the fingers touching both electrodes and mixer body at the same time (to carry off accidental electrostatic charge). If the crystal is handed

.../over

over to another person do it after touching his hand.

If the crystal cannot be placed in position when lightly pressing it, do not increase pressure but instead inspect the crystal (and mixer) and find the cause of trouble.

5. Screw the adapter connector tightly on the mixer and the feeder connector of the I.F. preamplifier on the adapter connector.

When choosing a crystal make sure that its noise current is minimum and ringing value is maximum. For this purpose plug instrument AVO-5 (scale 60 microA) into socket DIODE CURRENT (G2-1) of the range channel amplifier unit and measure noise current. Instrument CRYSTAL CURRENT should read 0.2 to 0.6 mA at maximum ringing time on the screens of the range indicators. The noise current value is considered normal if the current equals 8 to 15 microA at the receiver maximum amplification.

After that switch on high voltage and tune the high-voltage elements of the receiver system by the maximum ringing (See Section 5 of the present Chapter). If the ringing value is not less than that obtained previously (with the same magnetron) leave the crystal, otherwise choose another one repeating the above operations.

When replacing the crystal of the AFC mixer check for evidence of crystal current (at least 0.2 mA) and for normal operation of the AFC system (See "Tuning and Checking the AFC System", Section 4 of the present Chapter).

Klystron Replacement

The klystron is damaged, if:

- Instrument CRYSTAL CURRENTS indicates no current with the local oscillator rectifier operating.

- Crystal currents are unstable with the receiver system tuned, operating conditions of the oscillator normal, contacts of the receiver high-frequency channel elements in order.

.../- The

- The klystron frequency changes continuously or by steps with time.

- The value of echo pulses during the station operation and ringing value are unstable when tuning by the echo box.

Before replacing the klystron check the station for proper tuning as instructed above.

Replace the klystron only if you are absolutely sure that the local oscillator voltages are set properly and the receiver system and station high-voltage channel are tuned.

Replace the klystron, in the following sequence:

1. Disconnect the cables coupling the I.F. preamplifier unit with the mixers. Disconnect the cables running to the mixers from the klystron chamber.

2. Take out the local oscillator and place it in position suitable for operation.

3. Remove the cable coupling connector TO ECHO BOX with the cavity circuit from the lead of the klystron cavity circuit coupling loop.

4. Take out the cap of the klystron repeller lead.

5. Loosen the stop screw in knob KLYSTRON FREQUENCY and remove the knob.

6. Unscrew the screws securing the klystron cavity circuit to the front panel, holding the cavity circuit with a free hand. Take out the cavity circuit gently (toward the chassis rear) and remove the valve socket from the klystron base.

7. Unscrew the upper and lower clamping rings in succession from the klystron cavity circuit and remove the clamping split washers.

Slacken the locking nuts and unscrew the oscillator tuning cores.

8. Unscrew the screws clamping the halves of the klystron cavity circuit, separate them and remove the klystron after noting its position.

9. Wash the klystron cavity circuit, tuning cores and a new klystron

.../with

with alcohol (to remove dirt, metal shavings and dust, oxidation and finger smudges) and dry them out.

10. Insert the new klystron in one half of the cavity circuit and connect both halves, care being taken not to crush the disc loads of the klystron grids. Screw in the clamping screws and closely tighten both halves of the cavity circuit by turning them evenly.

11. Insert the clamping split washers in the disc lead of the upper klystron grid.

Screw in the upper clamping ring carefully so as not to break the klystron. Make sure that the split washers are in place and do not overlap each other. Likewise insert the split washers in the disc lead of the lower klystron grid and screw in the clamping ring.

12. Screw the tuning cores in the klystron cavity resonator.

13. Carefully put the valve socket on the klystron base, place the klystron cavity circuit in position and secure with screws.

14. Attach the cable, coupling connector TO ECHO BOX with the cavity circuit, to the circuit coupling loop lead.

15. Place the oscillator tuning knob in position andsecure it with a stop screw.

16. Place the unit in position.

Tune the receiver system as instructed in this Section.

Note: Place the loops coupling the klystron cavity resonator with the mixer and connector TO ECHO BOX in parallel with the vertical axis of the cavity resonator and secure them by a locking nut. When tuning the oscillator see that the tuning cores in the klystron cavity resonator are screwed in to an even depth.

Replacement and Selection of Discharge Valve ZG-5

The features characterising the malfunction of the discharge valve are as follows:

- Drop in the receiver system sensitivity at normal tuning of the system and normal sensitivity of the intermediate-frequency amplifier

checked according to Section "Tuning the Receiver System by means of Signal Generator".

- Sharp decrease of the signal mixer crystal current and failure to obtain normal value of the crystal current.

The discharge valve quality may be determined by the valve current. Therefore, check first of all the current value of the discharger valve for which purpose:

- With the transmitter high-voltage off remove the ignition electrode on the T.R. cell and place instrument AVO-5 (scale 300 microA) in series with the ignition circuit.

- Apply transmitter bias and record the discharger current value which should be within 80 and 200 microA.

The discharger proves faulty if the current value is abnormal or there is no current. In this case overhaul the T.R. cell and check the discharger for continuity and make sure that there is contact between the ignition connector and discharger.

Check the discharger current value periodically at least once a month. If the discharger current value considerably differs from those measured during previous checks replace the discharger.

To replace the discharger, proceed as follows:

1. Switch off the station.

2. Remove the magnetron observing the rules and sequence of operations mentioned in Section 3 "Magnetron Replacement".

3. Cut off the T-junction from the feeder of the antenna-feeder system.

4. Cut off the cables on the klystron cavity circuit that run to the mixers as well as the cables running from the mixers to the I.F. preamplifier unit.

5. Unscrew the screws securing the T.R. cell to the support and

.../remove

remove it from the magnetron compartment.

6. Dismantle the T.R. cell for which purpose:

- Unscrews the screws fastening the upper and lower cell covers and remove the latter.

- Unscrew the screws clamping detachable half-rings of the T.R. cell, care being taken not to damage the rubber gaskets and discharge valve. Take out the rubber gaskets and part the half-rings.

- Remove the discharger having noted the way the copper-gilded discs are inserted in the detachable half-rings.

- Loosen the locking nuts and screw the tuning cores out of the half-rings.

7. Wash the half-rings, tuning cores and new discharger in alcohol, and dry them. In this case remove metal shavings and dust, traces of oxidizing, dirt and finger-prints from the threaded parts and cavity of the detachable half-rings.

8. Make sure that the mixer coupling loop is placed in parallel with the vertical axis of the T.R. cell and the mixer is properly secured in the half-ring of the T.R. cell.

9. Insert the new discharger and assemble the cell. In this case:

- The discharger should be inserted in the half-rings without applying force and be freely turned by hand when the covers are not tightened (deformation of the discharger disc edges is not tolerated).

- Before tightening the covers the discharger should be centred in the half-rings.

- The spring contact of the ignition electrode in the cell cover should be placed so as to ensure the contact in symmetry with the centre of the discharger base (this is checked by the scratches on the base produced by sharp edges of the spring contact).

- The screws should be uniformly tightened around the edges of the

.../covers

covers to ensure their correct installation.

Should the above requirements not be complied with, the discharger may be damaged.

10. Place the T.R. cell in position. Screw in the screws securing it to the support by hand and attach the T-junction to the feeder.

11. Install the magnetron carefully if an operating one is used (it is desirable that a faulty magnetron should be used when installing the T.R. cell).

12. Arrange the T.R. cell so that the axes of the union nut, T-junction and feeder are on the same straight line, and then fix on the support. Tighten the screws of the feeder joints evenly to establish reliable connection, care being taken not to disturb the setting of the T.R. cell.

13. Install the operating magnetron as instructed under Section 3 "Magnetron Replacement".

14. After the new discharger has been placed in position tune the station to the maximum ringing. Record the obtained ringing value and make sure that the ringing value does not fall after two hours of operation. Otherwise, replace the discharger again and check the quality of the T.R. cell assembly.

Tunings and Checks Made After Replacing Discriminator (Valve 6H6S)

When replacing discriminator valve 6H6S make sure that conditions mentioned in Items 4 to 7, Sub-section "Tuning and Checking the AFC System" are fulfilled. If not, adjust the discriminator zero frequency as instructed under Section "Tuning the Receiver System by means of Signal Generator" (Sub-section "Tuning and Checking the AFC Channel by means of Signal Generator").

Tuning the Receiver System by means of Signal Generator SG-1

Checking the main parameters of the intermediate-frequency amplification channel

The receiver I.F. amplification is checked by the signal generator

.../SG-1

SG-1 as shown in Fig. 261. In this case:

- Determine the resonance frequency of the receiver I.F. amplification.

- Measure the volt-ampere characteristic of the detector and determine the amplification factor of the I.F. amplification.

- Measure the pass band width of the receiver I.F. amplification.

- Measure the I.F. amplification sensitivity.

The construction of the mixer equivalent through which the signal generator is attached to the input of the I.F. preamplifier unit is shown in Fig. 262.

Determining the resonance frequency

1. Use the circuit shown in Fig. 260 for which purpose:

- Connect the cable running from the signal generator SG-1 output to the mixer equivalent.

- Attach the mixer equivalent output to connector Zw22-2 of the I.F. preamplifier unit by means of the cable coupling the mixer with the unit input.

2. Set jumper W1-3 on the amplifier unit of the automatic tracking channel in position +120 V. Turn the shafts of potentiometers AUTOMATIC SENSITIVITY CONTROL (R1-21), NOISE LEVEL SETTING (R2-3) and knob AMPLIFICATION (R1-44, R7-99) located on the amplifier units of the automatic tracking channel and automatic range finder clockwise as far as they will go (to the maximum amplification position).

3. Connect instrument AVO-5 (scale 60 microA) by means of a plug to jack G1-1 of the automatic tracking channel amplifier unit.

4. Switch on the receiver system.

5. Switch on the signal generator to produce sustained oscillations.

6. Set the value of the signal generator output signal at 15 microV to check the automatic tracking channel.

7. By rotating the knob that changes the signal generator frequency

.../determine

determine the resonance frequency of the automatic tracking channel amplifier by the maximum indication of instrument AVO-5. The frequency should be within 30±0.25 Mc/s.

To check the resonance frequency of the range channel amplifier, take all measurements prescribed in items 1 to 7 below, having plugged instrument AVO-5 in jack G2-1 of the range channel amplifier unit. In this case set the output voltage of the signal generator at 40 microV. The resonance frequency of the range channel amplifier is considered normal if it differs from that of the automatic tracking channel amplifier by not more than ±0.3 Mc/s.

Measuring detector volt-ampere characteristic and determining amplification factor of I.F. amplifier

The detector volt-ampere characteristic is measured to determine the amplification factor of the receiver system and is obtained by means of the signal generator SG-1 and valve volt meter WKS-7B.

In doing this proceed as follows:

1. Use the measurement circuit as shown in Fig. 260.

2. To measure the volt-ampere characteristic for the automatic tracking channel, attach the valve voltmeter WKS-7B to the input of the detector of the automatic tracking channel amplifier unit between point 4 of valve V1-7 and chassis.

   Note: Valve V1-7 must be inserted in the valve socket. Make the connecting wire running from point 4 of valve V1-7 to the contact of the radio-frequency head of the voltmeter as short as possible.

3. Shift selector switch W1-3 to position +120 V.

4. Switch on the receiver system. Reduce the receiver system amplification by knob AMPLIFICATION until the readings of instrument AVO-5 stop decreasing. Note the instrument reading (which equals the initial detector current).

5. Switch on signal generator SG-1 to produce sustained oscillations

.../ and set

and set the resonance frequency of I.F. amplification.

Having obtained the indication on the valve voltmeter change the value applied from the signal generator and enter the voltmeter and microammeter readings into the table as follows:

Valve voltmeter WKS-7B readings, V	AVO-5 instrument readings, micro A
0.5 1.0 1.5 - 6 6.5 7	

Use the obtained values to draw a graph of the volt-ampere characteristic of the second detector plotting the voltage values in volts measured by the valve voltmeter on the X-axis and values corresponding to the type AVO-5 instrument readings in micro-amperes on the Y-axis.

6. The volt-ampere characteristic of the range channel is measured similarly to that of the second detector, the valve voltmeter WXS-7B being connected to point 5 of valve V2-2 and chassis, whilst the microammeter to jack G2-1 (DIODE CURRENT) of the range channel amplifier unit.

Note: The measured volt-ampere characteristics are valid until valves V1-7 (6H6S)and V2-2 (6H6S) are replaced.

7. To determine maximum amplification factors of the channels, turn the shafts of potentiometers AUTOMATIC SENSITIVITY CONTROL, NOISE LEVEL SETTING and knob AMPLIFICATION to their extreme clockwise positions and place jumper W1-3 to position +120 V.

8. Switch on the receiver system. Determine the detector voltage input caused by the system set noise according to the readings of instrument AVO-5 and detector volt-ampere characteristic.

9. Switch on the signal generator to produce sustained oscillations.

.../Set

Set the generator frequency equal to the resonance frequency of the I.F.A. channel and the following output voltages:

- 15 microV to check the amplification factor of the automatic tracking channel.

- 40 microV for the range channel.

10. Using the detector volt-ampere characteristic, determine the detector input voltage increment caused by the signal.

The amplification factor for both channels is determined as the quotient of the output voltage divided by the value of the input voltage applied from the signal generator SG-1.

The amplification factor should amount to:

- automatic tracking channel - at least 200,000.

- range channel - at least 75,000.

Measurement of Pass Band Width of I.F. Amplification of Automatic Tracking and Range Channels

To measure the pass band width of I.F. amplification, make all switchings mentioned in Items 1 to 6 of Sub-section "Determining resonance frequency".

The pass band should be measured as follows:

1. By changing the signal generator frequency within 27 and 33 Mc/s (in 0.5 Mc/s) note the microammeter readings corresponding to different frequencies.

Enter the data into the Table given below:

Signal generator SG-1 frequency, Mc/s	Readings of AVO-5 instrument, microA
27.0	
27.5	
28.0	
-	
-	
32.5	
33.00	

Note: When changing the signal generator frequency, see that the generator output voltage is constant.

2. Use the obtained values to draw a graph of the frequency characteristic of the automatic tracking channel by plotting frequency values on the X-axis and the current value read by instrument AVO-5 on the Y-axis.

3. Switch off the signal generator supply and measure by instrument AVO-5 the value of the detector current caused by the receiver noise.

When measuring the frequency characteristic for the automatic tracking channel, set the channel amplification at 200,000 to 220,000 according to the values of the volt-ampere characteristic by using variable resistor R1-21 (AUTOMATIC SENSITIVITY CONTROL). The pass band is determined at a level of 0.5 of the maximum indication of instrument AVO-5 at the resonance frequency minus the noise current.

To measure the frequency characteristic for the range channel, plug instrument AVO-5 (for 60 microA) in jack G2-1 of the range channel amplifier unit. The output voltage of the signal generator must be set at 40 microV.

The pass band for the range channel is determined similarly, but the channel amplification is set by variable resistor R2-3 (NOISE LEVEL SETTING) at 75,000 to 85,000.

The pass band measured by this method should amount to:

- 2.2 to 2.8 Mc/s for the automatic tracking channel;
- 3 to 3.6 Mc/s for the range channel.

Measuring I.F. amplifier sensitivity

To measure the I.F. amplifier sensitivity, use the circuit as shown in Fig. 260. For this purpose proceed as follows:

1. Switch on the receiver system.

2. Place jumper W1-3 on the automatic tracking channel amplifier unit in position +120 V. Turn shafts of potentiometers AUTOMATIC SENSITIVITY CONTROL, NOISE LEVEL SETTING and knob AMPLIFICATION all the way clockwise (maximum amplification).

..../3.

3. Determine the receiver noise current (i_{noise}) by instrument AVO-5.

4. Determine the detector initial current (i_o) measured with knob AMPLIFICATION in the extreme counter-clockwise position.

5. Switch on the signal generator to produce sustained oscillations. Set the generator frequency equal to the resonance frequency and by changing its output voltage set such a value of the output signal at which instrument AVO-5 reads double value of the noise level minus the diode initial current, i.e.

$$i_{signal} = 2i_{noise} - i_o .$$

The obtained value of the signal generator SG-1 output voltage corresponds to the receiver system sensitivity for I.F. amplification, and should be:

- for the automatic tracking channel: not worse than 8 microvolts;
- for the range channel: not worse than 7 microvolts.

Besides, it is possible to determine the receiver system sensitivity including the high-frequency channel (from the antenna head input) by means of tester RT-10 (See Section "Checking the Receiver System Sensitivity by Tester RT-10").

<u>Tuning the I.F. amplifier by signal generator SG-1</u>

If the measured parameters differ from the values specified in the above Section obtain them by valve selection. In this case the valves must be checked by a valve tester beforehand.

When valve selection yields no satisfactory results tune the I.F.A. stages by changing inductance of the circuit coils by means of cores.

For tuning purposes use the circuit as shown in Fig. 261.

When tuning, proceed as follows:

1. Tune all the I.F.A. stages by the maximum readings of instrument AVO-5 to the intermediate frequency beginning with the final stage of the channel.

.../2.

2. Determine the resonance frequency of both I.F.A. stages.

3. Determine the pass band of each channel. In case the band is too narrow widen it by slightly detuning some I.F.A. stages (mainly final) in amplifier units of both channels.

4. Check the receiver system sensitivity for both channels. If the sensitivity is poor select valve V22-8 in the I.F. preamplifier unit.

Tuning and checking AFC channel by signal generator SG-1

Check how the AFC system is tuned consulting the block-diagram shown in Fig. 263. In doing this, proceed in the following sequence:

1. Attach the cable from the signal generator output to the mixer equivalent.

2. Couple the mixer equivalent output to connector Zw22-1 I.F. PREAMPLIFIER through the cable (connecting the mixer to the I.F. preamplifier input).

3. Connect instrument AVO-5 (scale 3 V) to point 8 of valve V22-4 and chassis.

4. Apply a signal of 20 mV from signal generator SG-1 and, while varying its frequency within 27 and 33 Mc/s (at the constant generator output voltage) enter the voltage value measured by instrument AVO-5 (U_{output}) in the Table given below:

$f_{carrier}$, Mc/s	U_{output}, V
27	
28	
29	
30	
31	
32	
33	

5. Use the obtained value to draw a graph of the discriminator frequency characteristic by plotting frequency values in mega-cycles on the

.../X-axis

X-axis and output voltage values in volts on the Y-axis.

In this case the characteristic should be positive on frequencies lower than the cross-over frequency and negative on frequencies higher than the cross-over frequency (See Fig. 76).

6. Use trimmer capacitor C22-12 (in the plate circuit of valve V22-3) to obtain as symmetrical discriminator characteristic as possible.

7. Use trimmer capacitor C22-14 to set zero of the discriminator characteristic to a position at which the frequency equals 30 ± 0.15 Mc/s.

The discriminator frequency characteristic may also be determined with the pulse amplifier stage taken into account (V22-5). In this case proceed as follows:

1. Plug the valve voltmeter WKS-7B in jack G22-1 (MONITORING).

2. Feed out the signal generator SG-1 pulse with 30 per cent intermodulation, 2 to 5 mV, within a frequency band covering 27 to 33 Mc/s and measure the frequency characteristic.

Note: When measuring the output voltage, do not take into account the voltmeter initial indication.

When finding the characteristic curve, plot (assumingly) the output voltage values on the Y-axis as negative at lower than cross-over frequencies and as positive at higher than cross-over frequencies.

It is possible to determine the discriminator band width and the AFC channel amplification by the frequency characteristic. The band width is determined by two maximum values of the output voltage: it should be equal to 2.3 to 3.3 Mc/s. The amplification factor is determined on any maximum of the frequency as the quotient of the output voltage value divided by the value of the signal generator SG-1 input voltage.

$$K = \frac{E_{output}\ \mathrm{mV}}{E_{input}\ \mathrm{mV}}$$

and should be at least 1,500.

Checking the Receiver System Sensitivity by Tester RT-10

Tester RT-10 may be used for checking the operation of the station

.../receiving

receiving channel and for obtaining optimum tuning of the high-frequency elements of the receiver system with a view to establishing the maximum radar range.

Prior to measuring the sensitivity tune the high-frequency channel to maximum ringing as instructed under Section 5 of the present Chapter.

When working with tester RT-10, follow the operating instructions that come with the instrument.

Preparing the station and tester for sensitivity measurements

When preparing the station, proceed as follows:

1. Determine the magnetron frequency by means of the echo box.

2. Switch off the transmitter high voltage without switching off the bias voltage.

3. Remove the antenna head and replace it with the adapter. Connect the adapter with tester RT-10 by means of 5-m, cable RK-29.

4. Prepare the tester for operation according to the operating instructions, switch it on and allow it to warm up for at least 20 min.

5. Set the maximum amplification of the receiver system by turning knobs AMPLIFICATION of the amplifier units of the automatic tracking channel and automatic range finder fully clockwise.

6. Connect jack DIODE CURRENT of the range channel amplifier unit with instrument AVO-5 (scale 60 microA) by means of pilot cable No. 1.

7. Shift selector switch MANUAL - AFC to position MANUAL.

Measuring sensitivity in continuous-wave operation

When measuring sensitivity, proceed as follows:

1. Tune oscillator RT-10 according to the chart, supplied with the instrument, to the magnetron operating frequency in continuous-wave operation.

.../2.

2. Set the oscillator attenuator to such a position at which the signal power attenuation is about 40 db.

3. Adjust the frequency of oscillator RT-10 according to maximum readings of instrument AVO-5, by rotating knob OSCILLATOR FREQUENCY. In this case see that the avometer AVO-5M pointer does not overshoot, for which purpose change the oscillator attenuator weakening.

4. Adjust the T.R. cell and klystron oscillator by knobs KLYSTRON FREQUENCY and REPELLER VOLTAGE to obtain maximum readings of instrument AVO-5M.

5. Measure sensitivity of the receiver system for which purpose:

- Shift selector switch CALIBRATION - MEASUREMENT, situated on tester RT-10 to position CALIBRATION and put down the readings of instrument AVO-5M which measures the detector current caused by the receiver system noise (i_{noise}).

- Turn knobs AMPLIFICATION located on the amplifier unit of the automatic tracking channel or automatic range finder unit fully counter-clockwise and put down the readings of instrument AVO-5 which measures the detector initial current (i_o).

- Shift selector switch CALIBRATION - MEASUREMENT to position MEASUREMENT and wait 2 or 3 min.

- Set the attenuator of oscillator RT-10 so that current i measured by instrument AVO-5M equals double the value of the detector current caused by the receiver system noise minus the detector initial current:

$$i = 2i_{noise} - i_o$$

- Read the value of the RT-10 oscillator output power attenuation (in db) on the attenuator scale. Add to the value obtained the attenuation in the adapter and cable (about 4 - 5 db) determined by the correction chart (for the instrument and cable).

The correction chart is made up by taking a series of comparative measurements of the receiver system sensitivity within the operating band

SECRET

.../with the aid of

with the aid of tester RT-10 using the cable supplied with the instrument and a long measuring cable. The difference in values of the output power level will characterise attenuation in the measuring cable and adapter.

The obtained total output power attenuation of oscillator RT-10 (in db) characterises the station sustained oscillation sensitivity and must be of the order of 70 db below 10^{-5} W.

Measuring the sensitivity in pulse operation
(by plan-position indicator)

When measuring sensitivity proceed as follows:

1. Feed out a pulse from jack G8-12 of the range unit to connector EXTERNAL SYNCHRONISATION of instrument RT-10.

2. Shift switch PULSE - CONTINUOUS WAVE to position PULSE.

3. Shift switch CALIBRATION - MEASUREMENT to position CALIBRATION and calibrate the output power of tester RT-10 according to its operating instructions.

4. Using the chart data set the duration of the pulse from oscillator RT-10 at 0.5 microsec. by operating knob PULSE DURATION.

5. Use knob DELAY TIME located on tester RT-10 to set the delay so that the pulse does not coincide with the range marker on the plan-position indicator.

6. Adjust the tester oscillator by the maximum pulse amplitude on the screen of the coarse range indicator (cut in the attenuator if the pulse is saturated).

7. Adjust the klystron oscillator (by means of knobs KLYSTRON FREQUENCY and REPELLER VOLTAGE) and T.R. cell until the maximum amplitude of the pulse from tester RT-10 is obtained on the screen of the coarse range indicator (cut in the attenuator if the pulse is saturated).

8. On the attenuator scale read the db loss of the tester oscillator output power at which a pulse display of 0.5 microsec. duration fades out

.../on the screen

on the screen of the plan-position indicator.

The obtained value of the oscillator output power loss characterises the station sensitivity in pulse operation and must be by 3 to 5 db higher than the sustained oscillation sensitivity.

After tuning the high-frequency channel and obtaining the value of sensitivity that complies with the above data, proceed as follows:

1. Remove the adapter from the cable and place the antenna head in position.

2. Switch on the transmitter high voltage.

3. After the magnetron has been heated check the tuning of the receiver system by the maximum ringing as instructed under Section 5 of the present Chapter.

4. Check the operation of the AFC system as instructed under Sub-section "Tuning and checking the AFC system", Section 4 of the present Chapter.

5. CHECKING OPERATION OF STATION BY MEANS OF ECHO BOX

The echo box may be used for measuring the frequencies of the transmitter magnetron oscillator and receiver local oscillator, making relative checks of the magnetron oscillator power output, analysis of frequency spectrum of the high-frequency pulse, checking of the station.

To check the operation of the station with the help of the echo box, prepare first the echo box for operation.

Preparing the Echo Box for Operation

To prepare the echo box for operation proceed as follows:

1. Fix the rod bearing the echo box antenna in the rear left corner outside the trailer with the aid of the bracket.

2. Couple the antenna cable connector with the echo box cable connector located in a recess on the outer left-hand wall of the trailer.

.../Note

Note: When the echo box is not used keep its antenna with tube rod and cable in the cabin on the main control board. After the cable has been disconnected close the connector on the trailer outer wall with a cap.

3. Reciprocally orient the antennas of the station and echo box to obtain maximum coupling between them. For this purpose fix the echo box antenna on the supporting tube rod so that it is aimed at the station antenna. Grasp the reflector bracket and aim the station antenna at the echo box antenna horn. After that rotate the antenna head manually (REFERENCE VOLTAGE GENERATOR and INTERLOCKING must be off) to set the dipole in a horizontal position in parallel with the echo box antenna radiator. In this case the dipole half located on the outer surface of the feeder must be positioned on the right as viewed from the echo box antenna side.

The echo box measurements may be taken not less than 10 min. after the station is switched on.

Tuning the Receiver System

To tune the receiver system, proceed as follows:

1. Prepare the echo box for operation.

2. Switch on the station.

3. Rotate the echo box knob to tune the echo box to maximum reading of its indicator.

4. Turn knobs AMPLIFICATION located on the amplifier units of the automatic tracking unit and automatic range finder fully clockwise, shift selector switch MODE OF OPERATION to position MANUAL and selector switch AFC - MANUAL located on the I.F. preamplifier unit to position MANUAL.

5. Rotate the station antenna in azimuth and elevation by the handwheels to obtain maximum ringing time on the screens of the range indicators (switch INTERLOCKING is on).

Note: Even with the receiver system greatly detuned the screens of the range indicators will show a noticeable stretching of the direct transmitter pulse on account of the ringing pulse when tuning the echo box cavity resonator.

.../6.

6. Use knobs KLYSTRON FREQUENCY and REPELLER VOLTAGE to adjust the oscillator frequency until ringing of long duration (of the order of some thousand metres on the scale) is obtained on the screen of the course range tube.

7. Slacken the locking nuts of the T.R. cell adjusting screws and adjust the T.R. cell to maximum ringing by rotating the screws, after which secure them with the locking nuts.

8. Using the mixer adjusting screw, set the value of the mixer crystal current at 0.2 to 0.6 mA. Select the length of the line being adjusted and coupling with the oscillator (by the mixer adjusting screw) so that the noise current measured by instrument AVO-5 (scale 60 microA) connected to jack G2-1 is minimum at the maximum ringing value.

The matching of the mixer with the klystron oscillator should ensure continuous variation of ringing and crystal current of the signal on a section of at least half the value of ringing (on the scale) when changing the klystron oscillator frequency by knob REPELLER VOLTAGE on either side of the ringing maximum. Noticeable current jumps, fading and flickers of ringing on the section of continuous slope should not be observed.

Note: Make the adjustments specified in this point several times as they are interconnected.

9. Determine the ringing time by measuring the distance to the point in which the echo box signal fades into the background noise (Fig. 237). Take readings off the screen of the fine range indicator. For this purpose turn knob STROBE WIDTH (located on the range unit panel) clockwise so as to brighten approximately two revolutions of the sweep on the screen of the fine range indicator. Align the reference mark of the fine range indicator disc made of plexiglass with the point in which the echo box signal fades into the background noise (Fig. 237, b). Take readings off the range scale aligning the first spot of the electronic marker with the reference mark of the disc. The position of this point is independent of

.../those

those of knobs AMPLIFICATION situated on the panels of the automatic range finder and automatic tracking units and knob NOISE LEVEL SETTING on the panel of the range channel amplifier unit as long as the noise with an amplitude of at least 1 mm is seen on the tubes.

Note: To estimate the changes of the receiver system amplification factor when making complete tuning of the high-frequency channel, use is made of the value of the saturated ringing section up to the point in which the noise begins to appear above the saturation level. As shown in Fig. 236 the size of this Section is mainly dependent upon the amplification and saturation level of the receiver system, but it does not characterise the system sensitivity and cannot be used for comparative checking of the station high-frequency elements.

When determining the ringing time, make sure that the ringing pulse end does not coincide with the signals returned from a cluster of ground features, which may distort the measurement results.

10. Compare the obtained ringing time with the value found earlier when tuning the station high-frequency elements and entered in the Log Book. With selector switch AFC - MANUAL in both positions, the measurement difference should not exceed 150 m.

This comparative checking may be made only when the same magnetron is used because the duration of oscillations in the echo box circuit depends upon the magnetron frequency.

It should be borne in mind that sometimes variation of the ringing time (with unchanged tuning of the receiver system) may result from some changes in the transmitter system and antenna-feeder system when replacing the echo box crystal, changing the magnitude of coupling in the echo box and when disturbing the contacts in the high-frequency connectors of the echo box cables.

11. After the checking or tuning of the receiver system is over, detune the cavity resonator of the echo box so as to minimise the ringing pulse duration on the screens of the range indicator.

.../Checking the

Checking the Transmitter System Operation

Measuring the magnetron oscillator frequency

When measuring the magnetron oscillator frequency with the aid of the echo box, proceed as follows:

1. Rotate the knob of the echo box to tune it in resonance with the magnetron oscillator frequency; the resonance point is determined by the maximum reading of the echo box indicator instrument.

2. Note the position of the echo box scale at the maximum reading of the instrument indicator.

3. Determine the magnetron oscillator frequency corresponding to the reading of the echo box scale by the calibration chart.

Checking the relative power radiated by antenna

Do operations as instructed under Points 1, 2, 3, 4 and 5, Sub-section "Tuning the receiver system", Section 5 of the present Chapter to obtain the maximum reading of the echo box instrument indicator. Compare this reading with those of the instrument indicator entered in the log book of the station.

If these comparisons are done systematically, on the basis of this, changes of the power radiated during the radar operation can be determined. The readings may be compared only when the same magnetron is used or when magnetrons having the same operating frequency are used.

Spectrum analysis of magnetron-generated pulse

To analyse the frequency spectrum of the transmitter emission, proceed as follows:

First tune the echo box until its indicator reads a maximum value. After that turn the echo box knob about one revolution in either direction.

By slowly turning the knob in the opposite direction pass over the entire region of the magnetron-generated frequencies. Note the indicator readings and the appropriate readings on the scale. Using data obtained,

.../plot =

plot a spectrum curve of the magnetron-generated frequencies.

The form of the magnetron frequency spectrum is evidence of the proper tuning of the magnetron. Fig. 263 is a representation of typical spectra of the frequencies generated by the magnetron. The normal emission spectrum of the transmitter is shown in Fig. 264, a.

To make the most effective use of the antenna radiated energy divergences of frequencies (corresponding to the minima adjacent to the main maximum), should not appreciably exceed the pass band of the receiver and must be within 3.5 and 4.5 Mc/s (Fig. 264, a).

If the spectrum curve has a correct form, but low height of the main maximum this testifies to a low plate voltage on the magnetron or impairment of its vacuum (Fig. 264, b).

If the spectrum curve has no deep minima (Fig. 264, c) on both sides of the main maximum this means that the magnetron high-frequency pulse form is incorrect.

The presence of two maxima on the spectrum curve (Fig. 264, d) testifies to the generation by the magnetron of two types of oscillations on nearby frequencies or to pulling of the magnetron frequency caused by formation of standing waves in the feeder.

If the adjustment of the magnetic field and high voltage do not improve the spectrum, replace the magnetron.

6. PLAN-POSITION INDICATOR SYSTEM

Before switching on the plan-position indicator system check the position of knob BRIGHTNESS (R11-35) which should be turned fully to the left.

Switch on the power supply of the range measuring and plan-position indicator systems. Adjust the brightness and focusing of the sweep trace on the screen of the plan-position indicator.

Illuminate the indicator dial by turning knob DIAL ILLUMINATION

.../(R11-52).

(R11-52).

Use knobs MARKER BRIGHTNESS (R11-29) and STROBE BRIGHTNESS (R11-47) to set normal brightness of markers and strobe on the indicator screen.

Adjusting the Sweep Range

By turning the shaft of potentiometer SWEEP RANGE (R11-5) located on the panel of the plan-position indicator unit, set duration of the sweep on the indicator screen so that the number of range markers equals six.

Adjusting the Sweep Linearity

Turn the shaft of potentiometer SWEEP LINEARITY (R11-16) situated on the panel of the plan-position indicator unit to make sure that the intervals between the range markers on the sweep are (approximately) the same.

Matching the Range Markers with Range Zero Reading

Set the reading on the range mechanism scales at 20 km. Then using knob STROBE WIDTH located on the range unit, set the strobe width at 300 m. as measured by the fine range indicator.

Turn the shaft of potentiometer MARKER DELAY (R11-23) located on the panel of the plan-position indicator unit to match the second range marker with the strobe pulse pip.

Adjusting the Sweep Length

Adjust the sweep length by potentiometer SWEEP LENGTH (R11-19) located on the panel of the plan-position indicator unit so that the range markers are matched with the artillery grid placed in front of the indicator screen.

Adjusting screws SWEEP LENGTH and SWEEP LINEARITY are interdependent. Therefore, after the sweep length has been set adjust its linearity again and then set the length finally.

Adjusting the Position of Sweep Starting Point

The sweep on the screen of the plan-position indicator tube must start from the centre of the tube screen marked with a spot.

.../To adjust

To adjust the sweep starting point, proceed as follows:

1. Connect the plan-position indicator unit to the main control board by means of adapter cables.

2. Switch on the range measuring system, plan-position indicator and antenna positioning system.

3. Shift selector switch MODE OF OPERATION to position SCANNING and selector switch SCAN SELECTOR to position CIRCULAR.

4. Adjust the position of the focusing coil by means of knobs located on the coil fixing ring (Fig. 130).

Tube Replacement

When replacing the tube, put on protective goggles (against accidental burst).

Replace the tube in the following sequence:

1. Remove the plan-position indicator unit from the main control board.

2. Remove cap 2 with the valve socket from the tube base (Fig. 130).

3. Slacken screw 3 of the bracket which secures the tube neck.

4. Remove high-voltage cap 4 from the tube anode.

5. Remove framing 5 with a light filter having unscrewed four screws which secure the case to the unit front panel.

6. Replace the tube.

7. Secure the tube in place. Install the cap with valve socket and the high voltage cap.

8. After replacing the tube tune the plan-position indicator unit as instructed in the present Section.

7. TUNING THE ANTENNA POSITIONING SYSTEM IN AUTOMATIC TRACKING OPERATION

To tune the antenna positioning system in automatic tracking operation, switch on the station completely. Choose a separately located landmark producing a saturated signal on the range indicator screen. The blurred

.../portion of

portion of the pulse should make up not more than one third of its full amplitude (when estimating, adjust the receiver amplification so that the pulse does not reach saturation).

Tune the system in the following sequence:

1. Check the D.C. voltage between monitoring jack 75 V (G6-1) located on the automatic tracking unit and jack GROUND (G6-5). The voltage should be within 65 and 85 V.

2. Establish 3 volts D.C. between monitoring jack 3 V (G6-4) and jack GROUND, but turning the shaft of potentiometer 3 V (R6-12).

3. Using the manual control system, aim the antenna exactly at the selected landmark. In this case polarization of the echo signal will be at minimum.

By turning the range handwheel set the electric markers so that they are positioned in symmetry with the signal returned from the selected landmark on the screen of the fine range indicator.

4. Adjust the normal amplification of the receiver system range channel (See Section 4 "Checking and Setting the Receiver System Performances").

5. Set knob AMPLIFICATION (R6-8, R6-9), situated on the front panel of the automatic tracking unit, at divisions 5.

6. Apply voltage to the vertical deflection amplifier of oscillograph LI-125 from one of jacks COMMUTATOR INPUT (G6-6, G6-7) located on the front panel of the automatic tracking unit. Attach oscillograph terminal GROUND to jack GROUND (G6-5) of the unit.

The oscillograph screen will display the sine-wave of the error signal of 24 c.p.s. with the changes superimposed on the sine-wave on account of the signal polarization by the reflection from the landmark. The frequency of the changes is 48 c.p.s.

Adjust the oscillograph so that its screen shows three cycles of the error voltage of 24 c.p.s. and the error signal amplitude is about 1 cm.

.../when the antenna

when the antenna is off the target direction by 0-50.

7. Using the antenna control handwheels aim the antenna exactly at the landmark so that the error signal amplitude of 24 c.p.s. equals zero (the peaks of sine-wave, 48 c.p.s., should be located on the horizontal line).

8. Switch off the amplidynes and wait until they come to a stop. Then shift selector switch MODE OF OPERATION to position AUTOMATIC.

9. Adjust the normal amplification of the receiver system automatic tracking channel by turning the shaft of potentiometer SENSITIVITY CONTROL (R1-21) situated on the front panel of the unit. Fix the potentiometer shaft with a clamping nut in a position at which the signal amplitude becomes equal to two thirds of that when saturated.

10. Turn the shaft of potentiometer AUTOMATIC GAIN CONTROL (R6-6) located on the front panel of the automatic tracking unit and establish 6 - 7 mA on instrument ANODE CURRENT.

11. Press push-button ERROR SIGNAL, OFF (W4-5) situated on the panel of the range mechanism unit. The readings of instrument ANODE CURRENT should fall to zero.

12. Shift selector switch MODE OF OPERATION to position MANUAL and switch on the amplidynes. Use the antenna azimuth handwheel to turn the antenna clockwise by 0 - 50 off the target direction - the oscillograph screen will display the sine-wave of the error signal of 24 c.p.s.

13. Measure the error voltage across jacks COMMUTATOR INPUT (G6-6, G6-7) with the help of the oscillograph by connecting the input of the vertical amplifier in succession between either jack and jack GROUND. Turn the shaft of potentiometer BALANCE (R6-14) (located on the panel of the automatic tracking unit) to make sure that amplitudes of these voltages are equal.

Note: To measure voltages more precisely, switch off the horizontal sweep of oscillograph LI-125.

14. Switch off the amplidynes. Wait until they come to a stop,

.../then

then shift selector switch MODE OF OPERATION to position AUTOMATIC.

Notice the value of difference between the readings of two instruments FIELD CURRENT located on the front panel of the azimuth and elevation tracking unit with switch ELEVATION - AZIMUTH in either position. If the reference voltage generator is switched on correctly the difference should be greater with the switch in position AZIMUTH. In this position the left-hand instrument should read more than 25 mA, whereas the right-hand - less than 25 mA (the pointers are brought together). If not interchange the wires running to output terminals 3 and 5 of reference voltage transformer Tr13-1 situated on the control panel.

15. Shift selector switch FIELD CURRENT located on the front panel of the azimuth and elevation tracking unit to position ELEVATION. Make sure that both instruments readings are equal by turning the adjusting screw of the reference voltage generator (Fig. 265). For this purpose climb onto the cabin roof, unscrew the screws and remove the cap of the adjusting screw (on the reference voltage generator housing).

Then turn the screw with a screw-driver according to the instructions given from the cabin.

16. Switch on the amplidynes. Set selector switch MODE OF OPERATION at position MANUAL. By rotating the antenna control handwheels aim the antenna exactly at the landmark. In this case the error signal (24 c.p.s.) on the oscillograph screen will be equal to zero. Then by rotating the antenna elevation control handwheel clockwise tilt the antenna up by 0-50 from the landmark direction.

17. Switch off the amplidynes. Wait until they stop; then shift selector switch MODE OF OPERATION to position AUTOMATIC.

18. Set the switch of instruments FIELD CURRENT located on the azimuth and elevation tracking unit at position ELEVATION.

If the reference voltage generator is switched on correctly the left-hand instrument should read more than 25 mA, whilst the right-hand -

.../less than 25 mA.

less than 25 mA. Otherwise inter-change the wires running to output terminals 3 and 5 of reference voltage transformer Tr13-2 located on the control panel.

19. Shift the switch of instruments FIELD CURRENT to position AZIMUTH. Both instruments must read approximately the same values. If not, adjust the position of the reference voltage generator stator by means of the adjusting screw, this time without making the instrument readings equal, but only reducing the available difference twice.

Make the final adjustment of the stator position and potentiometers FEEDBACK in azimuth and elevation during automatic target tracking. For this purpose when tracking the target (desirably at a distance of 5 to 10 km.), proceed as follows:

- Place knob AMPLIFICATION located on the automatic tracking unit to position 5.

- Turn knob FEEDBACK of the elevation channel counter-clockwise as far as it will go. The antenna will start to oscillate continuously in elevation. Immediately, not to lose sight of the target, turn knob FEEDBACK clockwise until the fine elevation scale of the receiving selsyn unit moves smoothly (without sudden jumps).

It should be borne in mind that with large settings of knob FEEDBACK the pedestal movement will be sluggish and the antenna will fall behind the target or overrun it. Choose the most advantageous position of knob FEEDBACK in elevation.

- Make similar adjustment of the azimuth channel, watching the antenna motion by the fine azimuth scale located on the receiving selsyn unit.

After the above adjustments notice the position of knobs FEEDBACK in azimuth and elevation and make an entry in the log book of the station.

To make final adjustments of the reference voltage generator slowly turn the adjusting screw clockwise watching the target through the sight.

.../At a certain

At a certain moment the antenna begins to move in azimuth and elevation so that the target visible through the sight located on the station antenna will move in a circle around the sight crosshairs. Note the position when the antenna starts moving periodically in the reverse direction. Both extreme positions of the screw may be best determined by performing the above operation several times.

Set the adjusting screw to the mid-position between the two observed extreme positions, and make sure that the automatic target tracking is continuous and accurate.

Replace the cap of the reference voltage generator adjusting screw.

8. AUTOMATIC RANGE FINDER

Setting the Bias of Error Signal Discriminator

1. Set the antenna in a position where the range tubes will not display the ground echoes.

2. Set the automatic range finder amplification at maximum, for which purpose turn adjusting screw AMPLIFICATION located on the front panel of the unit fully clockwise.

3. Set the detector circuit bias, for which purpose connect instrument AVO-5 between jacks G7-9 and "earth" and set 50 volts, using adjusting screw BIAS.

4. Balance the D.C. amplifier for which purpose:

- Remove valve V7-17 from the automatic range finder unit.

- Switch on instrument AVO-5 to measure D.C. voltage across jacks G7-6 and G7-7.

- Operate adjusting screw BALANCE-2 to obtain zero voltage across the above jacks.

- Replace valve V7-17.

5. Make the split gate amplitude equal for which purpose turn receiver knob AMPLIFICATION fully counter-clockwise and balance the

.../system

system by adjusting screw BALANCE-3 (obtain a position at which the mechanism scales will not rotate).

6. Rotate knob AMPLIFICATION fully clockwise to set the receiver amplification and balance the system with the aid of adjusting BALANCE-1.

7. Set the operating amplification of the automatic range finder, for which purpose take bearing on the landmark and during automatic range tracking reduce the range finder amplification by screw AMPLIFICATION until the electronic markers stop oscillating in relation to the echo signal.

Adjusting the Video Amplifier Amplification and Setting the Bias of Automatic Gain Control Circuit

After all the station systems have been tuned make adjustments of video amplifier amplification and set the bias voltage of the automatic gain control circuit. For this purpose:

1. Aim the station antenna at an isolated landmark which produces a stable echo signal on the screens of the range indicators.

2. Set the electronic marker at the echo signal.

3. Shift selector switch MODE OF OPERATION to position AUTOMATIC.

4. Couple connector CENTRAL ELECTRODE located on the range indicator unit to jack G7-10 on the panel of the automatic range finder with the help of a pilot cable and shift switch OPERATION - CHECK situated on the range indicator unit to position CHECK.

5. Turn the shaft of potentiometer FEEDBACK (R7-36) located on the unit panel to set an amplification of the video amplifier which will produce a maximum signal on the tube screen; the signal should be without noticeable clipping (jack G7-10, Fig. 260).

6. By turning potentiometer AUTOMATIC GAIN CONTROL (R7-63) located on the unit panel set a bias voltage of the automatic gain control circuit which produces on the instrument on the panel a reading of 5 to 6 mA.

7. Disconnect the pilot cable and set switch OPERATION - CHECK to position OPERATION.

.../Balancing the

Balancing the Automatic Range Finder and Checking its Operation by Landmark

Make adjustments as instructed in Chapter 3, Section 2, Point 7.

9. ADJUSTING THE FRICTION CLUTCHES OF RANGE MECHANISM UNIT

Wrong adjustment of the mechanism friction clutch may increase errors when determining the range during automatic range tracking.

The range mechanism friction clutches should be adjusted so that:

- the range handwheel set in the tracking position remains motionless when the range mechanism is rotated by the motor;

- the range handwheel, set in the tracking position, can be rotated by the automatic tracking motor after the mechanism is locked in the extreme positions (i.e. outside 0 and 40 km.);

- manual range tracking (with the range handwheel tight on the friction clutch), and easy rotation of the range handwheel on the friction clutch after the mechansim is locked in the extreme positions of the handwheel is guaranteed.

When adjusting the mechanism friction clutches, proceed as follows:

1. Connect the range mechanism unit to the main control board by means of adapted cables.

2. Remove the upper cover from the unit.

3. Unscrew the plug located on the cover of the unit distribution mechanism (Fig. 266).

4. Feed voltage to the automatic tracking motor for which purpose set the shaft of potentiometer BALANCE-3 located on the unit panel in either of the extreme positions.

5. Rotate the differential friction clutch adjusting screw located under the plug to ensure that, with the adjusting screw tightened slightly, the range handwheel remains motionless when the mechanism is rotated by the automatic tracking motor.

.../6.

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6. Replace the plug in position.

After that check whether the requirements under point 3 are complied with. If not, slacken the locking nut securing the range handwheel and adjust the friction clutch with the nut.

Carefully check the handwheel for slipping on the friction clutch gently without jerks.

7. Fix the nut position with the locking nut (when tightening the locking nut hold the nut with a wrench).

10. REPLACING AND INSTALLING THE TUBES OF RANGE INDICATOR UNIT

Tube Replacement

To replace the tubes of the range indicator unit, proceed as follows:

1. Remove the range indicator unit from the main control board.

2. Remove the tube framing after unscrewing four retaining screws.

3. Take out the discs and then gently remove the cap from the central tube electrode.

4. Unscrew two screws securing the tube scale and remove the scale (be sure not to disconnect the wire running to the central electrode from the circuit).

5. Slacken four screws securing the tube socket to the screen.

6. Replace the tube.

7. Put on and secure the scale.

8. Put the cap on the central electrode and place the discs in position.

9. Attach the socket to the tube by four screws.

After the tubes have been replaced adjust the sweep forms, set the tubes by the trigger pulse and check the range zero reading.

In the stations of earlier design the tubes should be replaced as follows:

.../1.

1. Remove the upper cover from the rear wall of the unit.

2. Unscrew the central electrode protecting cap from the tube.

3. Remove the cap from the central electrode voltage supply conductor.

4. Remove the tube socket after unscrewing the screws securing it to the screen.

5. Replace the tube.

Tube Installation

Make sure that the range indicator unit multivibrators are tuned correctly.

Plug the pilot cable in jack G8-12 located on the unit panel; a trigger pulse will be seen on the tube screens.

The tubes should be installed so that the trigger pulse approximately coincides with zero division of the scales of the fine and coarse range indicators.

When installing the tubes, connect the range indicator unit to the main control board through adapter cables. After that slacken the locking nuts on three retaining screws of the tube socket and turn the tube the right way.

11. SETTING THE RANGE ZERO READING

The range zero should be set by correcting the position of the electronic marker relative to the range mechanism scales when matching the marker with the signal returned from the isolated landmark the distance to which is known to be within 1 m.

Set the zero range after all systems have been tuned. For this purpose:

1. Connect the range mechanism unit to the main control board through adapter cables. If the cover on the left side of the unit has no opening for the shaft of the phase shifter rotor remove the cover.

2. Switch on the station and let it warm up for at least 20 min.

.../3.

3. Aim the station antenna at the selected landmark. Turn knob AMPLIFICATION located on the automatic range finder unit to adjust the receiver amplification so that the echo signal on the range indicator screens is not limited.

4. Set the shaft of control ZERO SETTING situated on the range mechanism unit in the mid-position.

5. Set the range mechanism so that the readings of its scales correspond to the distance to the landmark.

6. Slacken the coupling that connects the shaft of the phase shifter rotor with the main shaft. By turning the phase shifter shaft set the electronic marker in symmetry with the echo signal. After that secure the coupling.

7. Place the unit in position. Perform operations described in Point 5 and check the position of the electronic marker. If the marker is not in symmetry with the signal reflected from the landmark set it correctly by turning shaft ZERO SETTING.

8. By turning the range handwheel match the end of the first spot of the electronic marker with the beginning of the leading edge of the trigger pulse. Enter the readings of the range mechanism scales in the station Log Book.

The range zero reading may be checked by the beginning of the trigger pulse consulting the entry in the log book.

This check must be made with the correct form of the fine range indicator sweep and with the properly tuned phase shifter. The distortion of the sweep and non-linearity of the phase shifter may cause a considerable fixed error in determining the range.

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.../Chapter 11

FAULTS, CAUSES AND REMEDIES

The station is essentially a complicated piece of equipment composed of a number of systems which in turn consist of various elements and components.

All these elements require definite conditions, proper operation and timely preventive maintenance to ensure normal working.

To quickly locate and correct faults, it is necessary to have perfect knowledge of the station equipment, to be well acquainted with the operating principle of the systems and the station as a whole, and to be skilled in repairing electrical and radio equipments.

When locating a fault, use the methods mentioned below to trace which elements are faulty, find out the cause and correct it.

When correcting faults, never make any alterations not provided for the circuit and specification.

1. MAIN CAUSES OF FAULTS

The main causes of faults are as follows:

1. Neglect of instructions on operation, transportation and storage of the station.
2. Failure to carry out or bad preventive maintenance and correction of located faults.
3. Failure of the electric vacuum devices (valves, cathode-ray tubes, magnetron, klystron, discharge valve, pilot and lighting lamps), electric machines (motors, selsyns, amplidynes, reference voltage generator, etc.) and separate elements and components (transformers, switches, chokes, magnetic starters, buttons, capacitors, relays, resistors, etc.).
4. Mechanical troubles resulting in breaks, short-circuits and reduction of insulance in the circuits of electric connections between the units and separate elements of the station.
5. Poor contact in the connectors, feeder joints and on terminal blocks

because of contamination, oxidizing and burning of contact surfaces and poor mechanical joint.

6. Failure of safety and paper fuses, thermal relays, measuring instruments and their shunts.

2. FAULT-FINDING PROCEDURE

To find the cause and place of trouble, and to locate the defective component, make use of the following methods:

a) Visual Inspection

b) Measurement

c) Separation (Elimination)

d) Replacement.

Visual Inspection

This method is used when locating faults in the antenna-feeder system, plug and feeder connectors during the checking of the units and elements before attempting to make any measurements in them. Inspect in the following sequence:

1. Examine the unit, element or component which is assumed to be faulty. Inspect electric contacts and other connections for mechanical damage, oxidation, burning and dirt.

2. Check the temperature of elements when the station is switched off and on (the temperature of the station elements may exceed the ambient air temperature by approximately 40^{o}).

When testing the valves make sure that the heater or cathode filaments are heated (valves with metal envelope should be checked by touch).

3. When checking the electric machines and drives, check for absence of jamming of the rotor shafts and make sure that they rotate in the normal direction. Every machine or drive produces a characteristic noise in operation which should be regularly listened to. An additional or abnormal noise is evidence of a fault.

4. Make sure that soldered areas in the wiring are reliable and the varnish coating is not damaged. Check for absence of contact between the soldered areas and the bare wires and for absence of contact to chassis. Check the earthing

and see that the wires are properly soldered to the shields and chassis.

5. Check for evidence of damage to fuses and make sure that the fuse links are intact.

6. Check to see that the varnish or enamel coating of the elements is not damaged and there are no traces of overheating or burning.

7. Check the remaining places which are liable to damage.

Measurement Method (Checking the Oscillograms and Measuring Voltage and Resistance Values)

If the fault is not found, then after visually inspecting the system, unit or element which is assumed to be defective a measurement method should be resorted to. This method should also be used when checking the circuits of the electrical connections between the system units and station elements.

When taking measurements, it is necessary to be well acquainted with key circuit diagrams and operating principles of the separate units, elements and the station as a whole. The key circuit diagrams of the unit, elements and circuit sections to be checked as well as the voltage and resistance charts, and oscillograms presented in this Chapter should be taken as a basis (Sections 4 and 5).

Measurements should first be taken in those circuits which are assumed to be faulty and then, if the initial measurements give no result check the unit or element step by step from the input to output. The measurements are taken in the following sequence:

Measurement of Voltages

The measurement of voltages on monitoring points and elements of the unit boils down to a comparison of the obtained results with those specified in the tables (permissible deviations taken into consideration).

If the measured voltage value differs from that in the chart by more than 15% and its value is not affected by the adjustments made in the unit (which is stipulated in the notes to the tables), the fault should be sought for in the circuits connected with the point on which the voltage differs from the chart voltage.

When measuring voltages, use instrument AVO-5M; in emergency cases use a D.C. valve voltmeter LWU-2, which is referred to in the notes to the voltage charts. The description and instructions on the use of instrument AVO-5M come with the instrument set.

Measure voltages with the system fully switched on and valves inserted. If the voltage is to be measured on the wiring side remove the unit from its compartment and connect it by means of adapter cables.

Measure voltages across the connectors of the main control board against the voltage chart of the control board with the unit removed and other units switched on. Compare the obtained results with the chart data taking into account the permissible deviations.

Checking with the Aid of an Oscillograph

The oscillograms of voltages across the monitoring jacks of the range system and plan-position indicator units can be observed by means of an oscillograph, type LI-125, which is supplied with the station standard equipment.

The description of oscillograph LI-125 and instructions for use come with the instrument set.

Before attempting to make any measurements, calibrate input potentiometer VERTICAL AMPLIFICATION of oscillograph LI-125. Select three points for calibration purposes.

1. Calibration No.1 (Fig. 267, a). Set selector switch AMPLIFICATION (in the vertical deflection channel) at position OFF. Then feed the mains voltage of 110 V, 427 c.p.s. from control panel PL13-7/1.4 to terminals INPUT of vertical deflection and set the sine wave amplitude on the oscillograph screen equal to 60 mm by means of knob VERTICAL AMPLIFICATION. In this case the oscillograph sensitivity for vertical deflection will be equal to 5 V/mm. Pencil a mark against the knob point.

2. Calibration No.2 (Fig.267, b). Set selector switch AMPLIFICATION (in the vertical deflection channel) to position ON. Feed an A.C. voltage of 6.3 V to terminals INPUT of vertical deflection from the filament points of a valve

socket of the unit to be checked. Set the sine wave amplitude on the oscillograph screen equal to 18 mm with the help of knob VERTICAL AMPLIFICATION and pencil a mark against the knob point. In this case the oscillograph sensitivity for vertical deflection is 1 V/mm.

3. Calibration No.3 (Fig.267, c). Set selector switch AMPLIFICATION (in the vertical deflection channel) at position ON. Feed an A.C. voltage of 6.3 V to terminals INPUT of vertical deflection from the filament points of a valve socket of the unit to be checked.

Use knob VERTICAL AMPLIFICATION to set the sine wave amplitude on the oscillograph screen equal to 60 mm and pencil a mark against the knob point. In this case the oscillograph sensitivity for vertical deflection is 0.3 V/mm.

To measure the oscillograms of voltages across the unit monitoring jacks, proceed as follows:

1. Connect terminal EARTH of the oscillograph vertical deflection input to the chassis of the unit being checked, and the second output lead of the vertical deflection amplifier - to the jack on which the oscillogram is checked.

2. Set knob VERTICAL AMPLIFICATION in a position corresponding to the calibration point (shown on the oscillogram figures). In this case after the sweep frequency (synchronization) has been adjusted the oscillograph screen LI-25 should display a curve whose form and amplitude look like those shown on the figure in this Chapter (check tuned stage).

A difference in amplitude of more than ±25% or distortions of the form of the oscillogram on the monitoring jack of the tuned stage indicates that the valve or the stage circuit is faulty. At the same time the oscillogram of the sound stage may be distorted by the succeeding stage or, to a large extent, by the previous stage if it is not properly adjusted or faulty.

When locating the trouble, use a key circuit diagram and look for the trouble by checking the resistors and other elements of the stage.

The oscillograms of the transmitter system curves are checked by means of an oscillograph 25-I with a driven sweep.

The oscillograms are measured on the monitoring points of the driver and

/modulator........

modulator units and are compared with those given in this Chapter.

When checking the transmitting system voltages with oscillograph 25-I, proceed as follows:

1. Set the connector switch "Y" (located in the rear port of the oscillograph housing) in position OFF, and set the switch "X" in position ON.

2. Set the selector switch RANGE in position "2 microseconds".

3. Set the selector switch SWEEP in position DRIVEN.

4. Set the selector switch SYNCHRONIZATION in position EXTERNAL.

5. Set the selector switch SYNCHRONIZATION POLARITY in position " – ".

6. Connect the source of synchronization (Connector B-25-3 PULSE TEST on the modulator panel) with the jack EXTERNAL SYNCHRONIZATION on the right hand side of the oscillograph front panel.

7. Switch on the oscillograph, turn the knob of the potentiometer BRIGHTNESS. With potentiometers BRIGHTNESS and FOCUS adjust the sweep.

8. Apply the examined pulse to jacks "Y" at the back of the oscillograph housing.

9. Turn the knob GAIN to obtain a clear display of the examined pulse.

10. Set the switch LENGTH CALIBRATION in position ON.

11. Determine the pulse length by counting the number of calibration markers superimposed over the pulse, assuming that the interval between the calibration markers corresponds to 0.1 microsecond.

12. Compare the pulse display with the pulse shape shown on the graph given in this Chapter.

Measuring the Resistances and Checking the Circuits

Resistance values are measured and the unit wirings are checked for proper condition by means of instrument AVO-5M according to the resistance charts of the units presented at the end of this Chapter.

The resistance measurements boil down to a comparison of the results obtained with those specified in the chart. If the data obtained differ from the value given in the chart by more than 15% the fault should be looked for in the circuit under check. For this purpose check the circuit elements in

succession after making sure the influence of parallel circuits is excluded.

When measuring resistances, check the connection between the elements of the circuit under check and make sure that there are no breaks or accidental connections which may result in fault or failure of some circuit elements.

Measure resistances with the unit disconnected and valves removed. In this case put the unit on the folding table which comes with the station set, or arrange it in some place suitable for operation.

Resistance values exceeding 10 megohms and the insulation should be checked with a 500-V megger.

When examining the electric machines, check the windings (for breaks) and the insulation which should not be greater than 10 megohms.

Check for presence of electrical connections between the system units and station elements and for correct wiring according to the key circuit diagrams of the station.

The circuits incorporating a number of adapter elements should be checked as follows:

- Check the soundness of the common circuit. If the circuit is faulty separate it into several parts using adapter elements.

- Check the separate sections in succession dividing them into smaller ones until the fault is traced and its cause.

Measuring the Valve Parameters

The valves are tested by means of a valve tester II-14 supplied with the station spare parts and accessories. The operating characteristics and parameters of the valves are checked against the test charts of the instrument.

Elimination Method

This method consists in step-by-step elimination of the units or elements which are supposed to be faulty.

By using this method it is feasible to find out which element is causing trouble.

This method helps to find the element responsible for impairing the

/insulation......

insulation resistance, clutter on the indicator screens and a number of other troubles connected with mutual influence of the systems and elements.

Replacement Method

This method consists in a successive replacement of separate elements, which arouse suspicion and may be the cause of trouble, by sound elements of the same type.

The method is mostly used for finding defective valves. However by means of this method it is possible to locate faults in the selsyns, capacitors, crystals, fuses and some other elements.

It should be borne in mind that the cause of failure of a circuit element may result from its bad quality, extended service life and abnormal operating conditions. Therefore, use the replacement method rather carefully. Otherwise the sound element substituted for a defective one may fail too.

Use this method only in those cases when immediate repair is necessary or the trouble cannot be located by means of other methods.

Using the Pilot and Adapter Cables

The station standard equipment includes pilot and adapter cables which are kept in the spare parts case. These cables are intended to check the amplitude and wave forms of the voltages in the stages of the units and to connect the removed units to the main control board when looking for faults, checking and tuning the energised units.

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5. Pilot cable K6 is used when checking the transmitter pulse wave form. In this case one cable end is coupled to output connector Zw25-3 of the transmitter, and the other - to the oscillograph.

6. Pilot cables K7 and K9 are used for connection of the oscillograph, when checking voltage amplitudes and wave forms on the electrodes of the unit valves.

7. Pilot cable K10 serves to couple the range indicators to connector

/Zw-3 ....

Zw25-3 located on the front panel of the modulator, when checking the transmitter trigger pulse.

8. The adapter cables are intended for connecting the removed units to the main control board and are used in case of repairs, voltage checks of separate stages and tuning of the energised units. These cables terminate in knife-type connectors. Depending upon the number of contacts in the connectors use is made of appropriate cables.

9. High-voltage and high-frequency adapter cables are used in the same cases as the multicore cables and are coupled to the corresponding connectors situated on the units and in the main control board.

Notes: 1. Use cable I-25 to couple the removed range unit with the main control board (connector Zw8-2).
2. Use cable I-22 to couple the driver unit to the transmitter (connector Zw23-1).

Do not switch on the transmitter high voltage during the driver unit operation through the adapter cables.

/3. STATION FAULTS ....

SECRET

3. STATION FAULTS, POSSIBLE CAUSES AND REMEDIES

Transmitter System

Symptom	Possible Cause	Remedy
Abnormal noise of fan motors with switch W25-1 on.	Blown fuse B25-3, B25-4 or B25-5.	Replace fuse.
Inadequate air feed by magnetron cooling fan motor	Wrongly phased mains 220V, 50 c.p.s.	Interchange phase ends on block P125-2
White pilot lamp TIME RELAY fails to come on 40 to 60 secs. after switch W25-1 is on.	Faulty time relay.	Check time relay operation.
/Illegible/	a) Carbon deposit or poor connection between contacts in the motor power supply circuit.(*) b) Defective motor in the time relay.(*)	Clean contacts and remove the cause of poor connection (dirt, weak spring, etc.). Replace or repair the motor.
Bias will not be switched on when pressing push-button W25-2 (ON, SCREEN AND BIAS)	a) Faulty magnetic starter P25-1. b) No contact in circuit of interlocks W25-10, W25-9, W25-8, W25-7, W25-6, W25-5.	Clean contacts of push-button W25-2. Check interlocks W25-10, W25-9, W25-8, W25-7, W25-6, W25-5.
	c) Lack of current in phase feeding coil of magnetic starter electro-magnet P25-1; blown fuse B25-3 or B25-4.	Check 220 V mains; replace fuse.
	d) Faulty bias rectifier kenotron V25-8.	Check kenotron V25-8 and replace if necessary.
	e) Punctured paper in spark gap PB25-1.	Replace paper.
	f) Open or burnt contacts of relay P25-3.	Clean contacts or eliminate seizing.
	g) Blown fuse B23-1 in the driver unit.(*)	Replace fuse.
	h) Faulty rectifier valve L23-6 in the bias voltage rectifier circuit of the driver unit.(*)	Check the valve and replace if necessary.
	i) Dirty or burnt contacts of magnetic starter P25-1.	Clean contacts.
Fluctuating pointer of instrument Pp25-3 VOLTAGE CHECK with switch W25-4 in position "-1400".	Breakdowns in bias rectifier kenotron V25-8.	Replace kenotron.

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(*) Concerns only stations of the first series.

SECRET

High voltage will not be switched on when pressing push-button W25-3 ON - HIGH VOLTAGE.	a) Magnetic starter P25-2 will not be switched on.	Clean starter contacts P25-2.
	b) Overload relay P25-2 operates and opens supply circuit of magnetic starter electromagnet coil.	Check high-voltage circuit.
	c) Break in circuit of resistors R25-43,R25-44 or R25-45.	Check circuits of resistors R25-43, R25-44 or R25-45 and eliminate break.
	d) No contact of on-off buttons W25-3.	Clean contacts.
	e) No pulse is furnished from range unit; relay P25-8 fails to operate.	Check for evidence of trigger pulse on driver input.
Pointer of the instrument W25-3 VOLTAGE CHECK comes to rest beyond the red mark when switch W25-4 is set in position " +4000 ". Circuits of the +4000 V rectifier and the control circuits are in order.(*)	a) No trigger pulse is supplied from the range unit.(*)	Check for presence of trigger pulse at the input of the driver unit.
	b) Defective circuits of electronic relay, inverter or power amplifier.	Check the circuits.
	Faulty valve L23-1,L23-2, L23-3,L23-4, or L23-5.(*)	Replace faulty valve.
No reading on instrument Pp25-1 HIGH VOLTAGE when rotating knob of potential regulator Tr25-7 clockwise.	a) Break in circuit of series resistors R25-1 - R25-25 for instrument Pp25-1.	Check circuit of series resistors and eliminate break.
	b) Defective high-voltage rectifier.	Check rectifier wiring.
When rotating knob of potential regulator Tr25-7 clockwise, pointer of instrument Pp25-1 HIGH VOLTAGE deflects to left.	Improperly inserted or faulty kenotron V25-12 of high-voltage rectifier.	Check setting of kenotron or replace it.

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	b) Punctured paper in spark gap PB25-2.	Replace paper.
	c) Break in storage capacitor charging circuit	Check circuit and eliminate break.
Overheated plate of one of modulator valves GMI-30.	Defective modulator valve.	Replace modulator valve.
With increase of high voltage magnetron current grows excessively though voltage is insufficient.	a) Too wide gap between magnet poles.	Narrow gap between magnet poles.
	b) Defective damping diode V25-3,V25-4 or V25-5.	Replace defective damping diode.
	c) Wrongly inserted or faulty magnetron.	Check magnetron setting; replace magnetron.

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(*) Concerns only stations of the first series.

Pointer of instrument Pp25-2 MAGNETRON CURRENT continuously fluctuates.	a) Faulty magnetron. b) Breakdown in feeder or antenna head. c) Unstable triggering. d) Unstable operation of electron relay (V23-1) or inverter (V23-2) in driver unit. e) Poor connection in floating contact.	Replace magnetron. Check feeder. Set stable image of trigger pulse on range indicator and follow travel of trigger pulse from range unit to driver input. Replace valve V23-1 or V23-2. Remove magnetron and clean connection of magnetron with feeder.
During transmitter operation pointer of instrument Pp25-2 MAGNETRON CURRENT kicks to right.	a) Breakdown in one of driver valves GI-30. b) Breakdown in one of modulator valves GMI-30.	Replace faulty valve. Replace faulty valve.

Antenna System

Antenna evades target direction; automatic tracking system is tuned.	Wrongly installed antenna head; lug is not seated in recess.	Unscrew nut securing antenna head to reference voltage generator sleeve and check for proper assembly.
Absence of required air pressure in high-frequency feeder; automatic dryer pressure gauge gives no reading.	a) Antenna head cap removed b) Weak springs of outlet and inlet valves of automatic dryer compressor. c) Poor assembly of T.R. cell; absence of rubber gaskets. d) Poor flange joint; absence of rubber gaskets. e) Damaged rubber ring in back cover of reference voltage generator. f) Antenna head polysterene cap broken. g) Defective automatic air dryer. h) Air leakage in the electric packing washer in cut-off attenuator.	Put on cap. Replace springs. Overhaul T.R. cell. Check for presence of rubber gaskets. Install them, if none present. Overhaul feeder flanges. Remove two parts of feeder running from slow speed rotating elevation joint to reference voltage generator; replace ring and assemble feeder. Replace antenna head. Replace cap. Locate trouble and correct it. Eliminate air leakage.

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Puncture of radio-frequency energy in feeder; readings of instrument MAGNETRON CURRENT sharply change, characteristic squeak of puncture is heard in feeder.	a) Poor contact in feeder joints.	Locate point of puncture after inspecting and listening to joints of separate feeder sections beginning from magnetron to antenna head. Disconnect feeder joint. Remove carbon deposits with alcohol moistened rag. Firmly couple feeder joint.
	b) Feeder system was not blown off by dry air before switching on high voltage.	Dry out feeder system.
	c) Poor connection in floating contact; magnetron contact did not enter seat of floating contact.	Clean breakdown point with alcohol moistened cloth. Set magnetron properly.
Ringing value, echo box indicator readings and echo pulses sharply change when antenna rotates in azimuth or elevation; all units operate correctly.	Azimuth or elevation slow-speed rotating joint is clogged.	Remove corresponding slow-speed rotating joint of feeder. Dismantle, clean and wash it in alcohol. Assemble and place it in position.

Receiver System

Size of echo pulses on range indicators is unstable. Unstable automatic tracking.	a) Faulty crystal of signal mixer.	Replace crystal.
	b) Poor contacts in mixer high-frequency connectors and cables coupling mixer with klystron and I. F. preamplifier unit.	Check and restore contacts.
Abnormally high noise level, unstable noise on indicators. Crystal current is normal.	a) Abnormal operating condition of klystron.	Check and correct it.
	b) Klystron is loose in chamber.	Check klystron fastening.
	c) Faulty crystal of signal mixer.	Replace crystal.
Value of crystal currents cannot be set normal.	a) Poor contacts in mixer and tuned line connections.	Check contacts.
	b) Klystron K-11 lost emission or produces low power.	Replace klystron.
	c) Faulty discharger ZG-5	Replace discharger.
	d) Faulty crystal.	Replace crystal.

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	d) One of several valves of range channel is faulty.	Check valves by valve tester and replace faulty one.
Echo signals are present on range indicators, automatic target tracking is unstable, noise does not decrease on range indicators when taking bearing on landmark.	a) Faulty AGC valve V1-10. b) Faulty relay P1-1 or open relay circuit. c) Faulty valve in automatic tracking channel: V1-5,V1-6,V1-7,V1-8 or V1-9 d) Very narrow gate pulse is not applied to unit.	Replace valve. Replace relay or eliminate open circuit. Replace valve. Check for presence of very narrow gate.
No echo pulses on all indicators, klystron functions, crystal current is normal.	Faulty valve in receiver system.	Check all valves in succession by valve tester.
Lamp "+120 V" fails to come on in amplifier unit of automatic tracking channel.	a) Faulty kenotron V1-12. b) Blown fuse B1-2 or B1-1	Replace kenotron. Replace fuse.
Magnitude of stabilized voltage of +120 V in amplifier unit of automatic tracking channel is very high and does not decrease when rotating shaft of potentiometer R1-54.	Faulty valve V1-14 or V1-15.	Replace valve.
Lamp "+300 V" fails to burn in range channel amplifier unit.	a) Faulty kenotron V2-7 or V2-8. b) Blown fuse B2-1 or B2-2.	Replace kenotron. Replace fuse.
Lamp "-105 V" fails to burn in range channel amplifier unit.	Faulty kenotron V2-9.	Replace kenotron.
Lamp "+150 V" fails to burn in I.F. preamplifier unit.	Faulty kenotron V2-11.	Replace kenotron.
Lamp "+250 V" fails to burn in I.F. preamplifier unit.	a) Faulty kenotron V22-14. b) Blown fuse B22-1 or B22-2.	Replace kenotron. Replace fuse.
Magnitude of voltage of -250 V in I.F. preamplifier unit is high and cannot be set when rotating variable resistor R22-50.	Faulty valve V22-18 or V22-17.	Replace valve.
Sharp increase of noise.	Receiver excitation through range channel.	Decrease range channel amplification by knob NOISE LEVEL SETTING.
Disintegration of sweeps on coarse and fine range indicators.	Faulty valve in video amplifier or abnormal operation of +120 V stabilized rectifier in automatic tracking channel amplifier unit.	Replace faulty valve. Correct faults in rectifier.

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On the screens of the range indicators appears additional interference caused by the operating elements of the station.	a) Sparking in antenna driving motors.	Clean and wash commutators with alcohol. Check the brushes.
	b) Dirty rings of the antenna pedestal rotating joint.	Clean the rings of the rotating joint. Check the brushes.
	c) Sparking of electromagnet and relays.	Locate the sparking relay by method of elimination. Remove the cause of sparking.

Range Measuring System

No lighting on the range indicators tubes: A) The pilot lamp on the range measuring and plan-position indicator power supply unit is off.	a) Blown fuse B5-1 or B5-2 of the power supply unit.	Replace the fuse.
	b) Poor contact of the fuses B5-1 or B5-2.	Restore good contact.
B) The power supply pilot lamp is on.	a) Faulty valve V5-1.	Replace valve.
	b) Poor contact in the connector Zw5-1 or Zw3-4.	Restore good contact.
No lighting on one of the indicator tubes.	a) Poor contact in the tube socket.	Restore good contact.
	b) Faulty tube.	Replace tube.
The display on fine or coarse range indicator flickers.	Poor contact in the tube socket.	Restore good contact.
No sweep on the fine range indicator. Normal sweep on coarse range indicator.	a) Poor contact in the tube socket.	Restore good contact.
	b) Poor contact in the connector Zw8-2 or Zw3-2.	Restore good contact.
The fine range indicator displays straight line instead of a circle.	a) Poor contact in the tube socket.	Restore good contact.
	b) Poor contact in the connector Zw8-2 or Zw3-2.	Restore good contact.
No sweep on the fine range indicator. Impossible to obtain the sweep after the quartz crystal had been changed. Sweep on the coarse range indicator displays an ellipse instead of a circle.	Faulty valve V8-1.	Replace valve.
The sweep on the coarse range indicator is distorted or flutters when the range handwheel is rotated.	No synchronization of the 15 kc/sec. or the 3.75 kc/sec. multivibrator.	Adjust multivibrator.

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Coarse range indicator displays straight line instead of circumference.	a) Contact fault in tube socket. b) Contact fault in connector Zw8-2 or Zw3-2.	Restore contact. Restore contact.
Coarse range indicator is not gated but supplied with trigger pulse.	a) Faulty valve V8-15. b) Contact fault in connector Zw8-2 or Zw3-2. c) Contact fault in valve panel.	Replace valve. Restore contact. Restore contact.
No magnetron current. Sweep on plan-position indicator tube is blurred and poorly brightened:		
A) Normal voltage on jack G8-10.	No trigger pulse is supplied from range unit.	Replace valve V8-6 or V8-14.
B) Abnormal voltage on jack G8-12.	No trigger pulse is supplied from range unit.	Replace valve V8-13.
C) Normal voltage on jacks G8-9 and G8-12.	No trigger pulse is supplied from range unit.	Replace transformer Tr8-3.
No strobe pulse is seen on fine range tube. Coarse range indicator does not display electronic marker.	Faulty valve V8-16 or V8-9.	Replace faulty valve.
No strobe pulse is seen on fine range indicator. Coarse range indicator displays electronic marker.	a) Faulty valve V8-8. b) Contact fault in connector Zw8-2.	Replace valve. Restore contact.
Strobe pulse fails to move on fine range tube when range handwheel is rotated.	a) Faulty potentiometer R4-21 in range mechanism unit. b) Contact fault in connector Zw8-2. c) Faulty valve V8-10.	Clean current-collecting brushes. Restore contact. Replace valve.
No markers on plan-position indicator tube, normal voltage oscillogram on jack G8-5.	Faulty valve V8-8.	Replace valve.
Fine range indicator fails to display electronic marker; no very-narrow gate pulse applied to jack G3-3; electronic markers fail to appear when potentiometer BIAS B5-18 is rotated:	Contact fault in connector Zw8-2 or Zw11-1.	Restore contact.
A) No voltage applied to jack G3-3.	a) Faulty valve V3-2 or V3-3. b) Faulty transformer Tr8-3.	Replace faulty valve. Replace transformer.
B) No voltage applied to jack G3-2.	Contact fault in connector Zw8-2 or Zw3-2.	Restore contact.
C) No voltage applied to jack G3-1.	a) Contact fault in connector Zw3-6 or Zw4-2. b) Faulty valve V3-1.	Restore contact. Replace valve.

D) No voltage applied to jack G4-6.	a) Faulty valve V4-1. b) Faulty transformer Tr4-1. c) Faulty valve V4-2.	Replace valve. Replace transformer. Replace valve.
E) No voltage applied to jack G4-1.	Contact fault in connector Zw8-5 or Zw4-1.	Restore contact.
Fine range indicator displays no electronic marker; very-narrow gate pulse is applied to jack G3-3:		
A) No voltage applied to jack G3-4.	a) Faulty valve V3-4 or V3-5. b) Faulty transformer Tr3-6 or Tr3-7.	Replace faulty valve. Replace transformer.
B) Normal voltage on jack G3-4.	Contact fault in tube socket.	Restore contact.
Unstable sweeps on range indicators.	a) Faulty voltage divider R5-5 and R5-18. b) Faulty valve V5-1.	Replace faulty resistor. Replace valve.
Automatic tracking motor fails to rotate:		
A) Valves V7-15, V7-16 are not heated.	No 50 c.p.s. voltage applied.	Replace fuse B9-3 or B9-4 of range measuring system power pack.
B) No voltage applied to jack G7-11.	Faulty valve V7-11.	Replace valve.
C) No voltage (450 V) applied to jack G7-2.	Blown fuse B9-1 or B9-2 of range measuring system power pack.	Replace fuse.
D) Milliammeter Pp7-1 reads no current.	Faulty valve V7-13.	Replace valve.
Readings of instrument Pp7-1 will not change when automatic amplification is controlled.	a) No signal is furnished from receiver automatic tracking channel. b) Faulty valve V7-14.	Check contacts in connectors Zw7-5 and Zw6-3. Replace valve V7-14.
Automatic tracking motor rotates rapidly with no video signal applied.	a) Faulty valve V7-15 or V7-16. b) Unbalanced automatic range finder.	Replace valve. Balance unit.
Automatic range finder fails to hold target. Target echoes are seen on range tubes:		
A) No signal and noise on jack G7-10; split gate pulses are applied.	a) Faulty valve V7-6, V7-7 or V7-8. b) No video signal fed from receiver range channel	Replace faulty valve. Restore contact in connectors Zw7-4, Zw2-2.

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B) No split gate pulses applied to jack G7-10; signals and noise are present; fine range indicator displays electronic marker.	Contact fault in connectors Zw3-1 and Zw7-3.	Restore contact.
C) Jack G7-10 is fed with one split gate pulse only.	Faulty valve V7-1, V7-2, V7-4 or V7-5.	Replace faulty valve.

Plan-Position Indicator System

No display on screen and no heater voltage applied to valves of power pack of plan-position indicator and range measuring systems.	Blown fuse B5-1, B5-2, B5-3 or B5-4.	Replace blown fuse.
Sweep on screen can not be focused.	Faulty focus potentiometer R11-50.	Replace potentiometer.
Sweep and markers double; sweep trace width changes when antenna rotates.	Scale illumination lamps contact to chassis.	Correct fault.
No range markers displayed on screen.	a) Faulty valve V11-5 or V11-6 (left-hand triode). b) Wrongly adjusted potentiometer R11-23 MARKER DELAY.	Replace faulty valve. Adjust potentiometer.
Range markers double on screen.	a) Faulty marker delay potentiometer R11-23. b) Non-adjusted multivibrator 15 Kc/s V8-2 in range unit.	Replace potentiometer. Adjust multivibrator or replace valve V8-2.
No echo pulses displayed on screen; sweep and range markers provided.	Faulty valve V11-7.	Replace valve.
No sweep displayed on screen.	a) Faulty valve V11-4, V11-3 or V11-2. b) Contact fault between lugs of deflecting coils and slip-rings.	Replace faulty valve. Restore contact having turned contact screws so that lugs touch slip-rings.
Irregular rotation (jerks) of sweep with antenna rotating.	a) Poor contact between brushes and slip-rings of plan-position indicator selsyn M11-1 or transmitting selsyn M32-5. b) Dirty gears of sweep rotation mechanism.	Clean selsyn brushes and slip-rings. Clean rotation mechanism.
Sweep fails to rotate with antenna rotating.	a) Faulty valve V11-11 or V11-12. b) Contact fault in connector Zw11-2 or Zw9-2.	Replace faulty valve. Restore contact.

Flicker and poor brightness of sweep; magnetron current is normal.	a) Faulty valve V11-1. b) Poor contact in connector Zw11-3 or Zw8-4.	Replace valve. Restore contact.

Antenna Positioning System

Antenna misses target direction when changing over to automatic tracking; readings of instrument on automatic tracking unit decrease when target is covered by strobe pulse.	a) Non-adjusted balance in azimuth and elevation tracking unit.	Set balance in azimuth and elevation by appropriate potentiometers BALANCE located on unit front panel.
	b) Wrongly set antenna head.	Set antenna head correctly.
	c) Wrongly adjusted reference voltage generator.	Make adjustment of generator.
	d) Faulty valve V6-4.	Replace valve.
Erratic automatic tracking. During tracking of targets producing weak reflection, paraboloid misses target direction.	a) Faulty valve V6-2, V6-3 or V6-4.	Replace faulty valve.
	b) Non-adjusted potentiometer AUTOMATIC GAIN CONTROL or AMPLIFICATION in automatic tracking unit.	Adjust potentiometer located on front panel of unit.
Antenna cannot be controlled in azimuth or elevation.	a) Faulty valve V10-53 or V10-3.	Replace faulty valve.
	b) Contact fault on brushes of elevation selsyn-transformer M32-54 or azimuth selsyn-transformer M32-4.	Restore contacts in selsyns.
	c) Contact fault in springs of relays P10-2, P10-1.	Restore contact.
Antenna does not move in azimuth and elevation. Pilot lamp on automatic tracking unit is burning.	a) No power is fed to selsyns.	Check supply circuits of selsyns.
	b) No field voltage is applied to drive motors.	Check operation of field rectifier.
Considerable antenna hunting in azimuth and elevation during manual control.	Poor contact in brushes of selsyn M12-1 or M12-51 in antenna control unit, selsyn-transformers M32-4 and M32-54.	Check selsyn brushes, wipe slip-rings.
Spontaneous oscillation of antenna in azimuth or elevation.	a) Faulty valve V10-6, V V10-7, V10-56 or V10-57.	Replace faulty valve.
	b) Wrongly set azimuth or elevation knobs FEEDBACK in azimuth and elevation tracking unit.	Adjust feedback.
During circular scanning antenna rotates with jerks; adjustment has no effect.	Jamming in mechanism imparting rotation from plan-position indicator system motor to selsyns in	Eliminate jamming in mechanism.

Antenna fails to move off stop in extreme upper or lower position.	a) Limit switches W32-51, W32-52 are defective or shorted to earth. b) Burnt contacts of relay P32-1, P32-2 or P32-3.	Repair limit switches located in antenna pedestal. Clean contacts.
Abnormal noise of reference voltage generator.	Faulty fast speed rotating joint.	Repair joint.

Data Transmission System

Receiving selsyn rotor rotates in wrong direction.	Wrong connection of wire ends to three-phase winding of receiving selsyn rotor.	Interchange two wire ends attached to selsyn rotor.
Receiving selsyn rotor rotates now in correct direction, now in wrong direction.	Discontinuity in wire of selsyn rotor three-phase winding.	Restore circuit.
Irregular rotation of receiving selsyn rotor in correct direction.	a) Dirty slip-rings or brushes of selsyn. b) Jamming in selsyn scale.	Wipe slip-rings or brushes. Remove framing and eliminate fault.
Selsyn rotor sticks in one position, selsyn gets hot.	Two selsyn rotor wires are short-circuited.	Remove short circuit or replace selsyn.

Echo Box

Indicator pointer fails to deflect: A) No signal from echo box is displayed on range indicator.	a) Break or short circuit in echo box cable. b) Contact fault in connectors.	Check cable. Check connectors and restore contact.
B) Normal signal from echo box is displayed on range indicator.	a) Faulty crystal detector of unit. b) Faulty echo box circuit. c) Unit switch in position x10.	Remove echo box cover and check crystal. Check circuit. Set switch in other position.

.../4. RESISTANCE AND

4. RESISTANCE AND VOLTAGE CHARTS

Resistance Chart

Measurement between points		Resistance Values	Elements included in circuit	Notes
Automatic tracking channel amplifier unit				
V1-1,contact 4	Zw1-6,contact 4	70 kilohms	R1-2,R1-41 R1-42,R1-43 R1-44,R1-60 R1-61,L1-1	
V1-1,contact 5	Zw1-6,contact 4	100 ohms	R1-3	
V1-1,contact 6	V1-1,contact 8	470 "	R1-4	
V1-1,contact 8	V1-13,contact 1	800 "	R1-4,R1-5	
V1-2,contact 4	Zw1-6,contact 4	70 kilohms	R1-9,R1-41 R1-42,R1-43 R1-44,R1-60 R1-61,L1-2	
V1-2,contact 5	Zw1-6,contact 4	100 ohms	R1-8	
V1-2,contact 6	V1-2,contact 8	470 "	R1-7	
V1-2,contact 8	V1-13,contact 1	800 "	R1-6,R1-7	
V1-3,contact 5	Zw1-6,contact 4	100 "	R1-10	
V1-3,contact 6	V1-3,contact 8	470 "	R1-11	
V1-3,contact 8	V1-13,contact 1	800 "	R1-11,R1-12	
V1-4,contact 5	Zw1-6,contact 4	100 "	R1-15	
V1-4,contact 6	V1-4,contact 8	470 "	R1-14	
V1-4,contact 8	V1-13,contact 1	800 "	R1-13,R1-14	
V1-5,contact 4	Zw1-6,contact 4	270 "	R1-17	
V1-5,contact 4	V1-11,contact 4	270 "	R1-17	
V1-5,contact 5	Zw1-6,contact 4	56-1050 "	R1-16,R1-21	With R1-21 in extreme positions.
V1-5,contact 6	G1-3	100 ohms	R1-20	
V1-5,contact 8	Zw1-6,contact 8	1.33 kilohms	R1-19,R1-18	
V1-6,contact 5	Zw1-6,contact 4	100 ohms	R1-22	
V1-6,contact 6	Zw1-6,contact 8	62 kilohms	R1-25	
V1-6,contact 8	Zw1-6,contact 8	1.33 "	R1-23,R1-24	
V1-7,contact 3	Zw1-6,contact 4	4.3 "	R1-26,L1-8	
V1-8,contact 3, 6, 8	Zw1-6,contact 8	11.1 "	R1-30,R1-31	
V1-8,contact 5	Zw1-6,contact 4	1 "	R1-29	
V1-9,contact 4	Zw1-6,contact 4	240 "	R1-33	
V1-9,contact 5	Zw1-6,contact 4	1 "	R1-34	
V1-9,contact 6	Zw1-6,contact 8	0		
V1-9,contact 8	Zw1-6,contact 8	1.5 "	R1-35	
V1-10,contact 1,2	Zw1-6,contact 4	6.2 Megohms	R1-45,R1-46 R1-42	
V1-10,contact 3	Zw1-6,contact 4	133 kilohms	R1-38,R1-40	
V1-10,contact 5	Zw1-6,contact 4	24 "	R1-39,R1-40 R1-57,R1-54 R1-55	
V1-10,contact 6	V1-1,contact 4	330 ohms	R1-2	
V1-11,contact 5	Zw1-6,contact 4	100 "	R1-59	
V1-11,contact 6	G1-2	330	R1-58	
V1-11,contact 8	V1-11,contact 6	1 kilohm	R1-47,L1-10, R1-27	
Zw1-6,contact 6	G1-4	50 " s	R1-60	
V1-13,contact 1	Zw1-6,contact 4	24 "	R1-54,R1-55 R1-39,R1-40, R1-57	
V1-13,contact 3, 5, 6	V1-15,contact 5	78 "	R1-51,R1-52	

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V1-13,contact 6	Zw1-6,contact 4	900 kilohms	R1-48,R1-49 R1-53	
V1-14,contact 4	Zw1-6,contact 4	21.5-60 "	R1-54,R1-55 R1-39,R1-40 R1-57,R1-21	With R1-54 in extreme positions
V1-14,contact 6	V1-15,contact 5	39 "	R1-52	
V1-14,contact 8	Zw1-6,contact 4	800 "	R1-49,R1-53	
Zw1-6,contact 9	Zw1-6,contact 4	Not less than 50 megohms	Insulation resistance	W1-1 is on
Zw1-6,contact 10	Zw1-6,contact 4	"	"	W1-2 is on

NOTE: Take measurements with contacts 3,5 of connector Zw 1-6 closed.

Range channel amplifier unit

Zw2-1	Zw2-4,contact 3	200 ohms	R2-1	
V2-1,contact 5	Zw2-4,contact 3,4	56 ohms - 1 kilohm	R2-2,R2-3	With R2-3 in extreme positions
V2-1,contact 6	Zw2-4,contact 8	63 kilohms	R2-6,R2-5	
V2-1,contact 8	Zw2-4,contact 8	2.2 "	R2-4,R2-5	
V2-2,contact 8	Zw2-4,contact 3,4	2.2 "	R2-7	
V2-3,contact 4	Zw2-4,contact 3,4	222 "	R2-11,R2-10 R2-9,R2-20 R2-19	
V2-3,contact 6&8	Zw2-4,contact 8	29 "	R2-12,R2-13, R2-38,L2-4	
V2-4,contact 4	Zw2-4,contact 3,4	470 "	R2-16,R2-17	
V2-4,contact 5	Zw2-4,contact 3,4	150 ohms	R2-17	
V2-4,contact 3, 6, 8	Zw2-4,contact 8	14.7 kilohms	R2-14,R2-15, R2-39	
V2-5,contact 5	Zw2-4,contact 3,4	17 "	R2-18, R2-19, R2-20, R2-9 R2-10,R2-31	
V2-5,contact 4	Zw2-4,contact 8	18 "	R2-27	
V2-5,contact 3	Zw2-4,contact 8	1.5 "	R2-21-R2-26	
V2-5,contact 8	Zw2-4,contact 3,4	51 ohms	R2-30	
G2-21	G2-22	5.1 kilohms	R2-36	
Zw2-4,contact 5	Zw2-4,contact 3,4	1 "	R2-29	
Zw2-4,contact 3,4	Zw2-4,contact 3,4	0		
Zw2-4,contact 9	Zw2-4,contact 3,4	Not less than 50 megohms	Insulation resistance	W2-1 is on
Zw2-4,contact 10	Zw2-4,contact 3,4	"	"	W2-2 is on

Range indicator unit

Tr3-2,contact 4	Zw3-1,contact 9	470 kilohms	R3-6	
Tr3-2,contact 6	Tr3-2,contact 1	470 "	R3-7	
Tr3-3,contact 4	Zw3-1,contact 9	470 "	R3-9	
Tr3-3,contact 6	Tr3-3,contact 1	470 "	R3-8	
V3-6,contact 1	V3-6,contact 2	220 "	R3-2	
V3-6,contact 3	V3-7,contact 3	1.38 megohms	R3-11,R3-12, R3-24,R3-25	R3-13, R3-14 turned fully counter-clockwise
V3-6,contact 1	Zw3-1,contact 9	730 kilohms	R3-15,R3-16, R3-17,R3-18, R3-19,R3-20, R3-21,R3-22	
Zw3-4	Zw3-1,contact 9	100 "	R3-23	W3-1 in position OPERATION
Tr3-4,contact 4	Zw3-1,contact 9	470 "	R3-33	
Tr3-4,contact 6	Tr3-4,contact 1	470 "	R3-34	
Tr3-5,contact 4	Zw3-1,contact 9	470 "	R3-35	

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Tr3-5,contact 6	Tr3-5,contact 1	470 kilohms	R3-36	
V3-1,contact 1	Zw3-1,contact 9	470 "	R3-42	
V3-1,contact 3	Zw3-1,contact 9	1 "	R3-43	
V3-1,contact 4	G3-1 or Zw3-1,contact 9	33 "	R3-44	
[illegible]-1,contact 5	Zw3-1,contact 5	15.3 "	R3-38,R3-40 R3-41	
V3-1,contact 2	Zw3-1,contact 5	10 "	R3-39	
V3-2,contact 8	Zw3-1,contact 5	10 "	R3-47	
V3-2,contact 6	Zw3-1,contact 5	100 "	R3-48	
V3-2,contact 3	Zw3-1,contact 3	100 "	R3-49	
V3-2,contact 4	Zw3-1,contact 9	7 ohms	R3-45,L3-2	
V3-2,contact 5	Zw3-1,contact 9	15 kilohms	R3-46	
V3-3,contact 1,4	Zw3-1,contact 4	22 "	R3-50,Tr3-8	
V3-3,contact 2,5	Zw3-1,contact 7	10.1 "	R3-5,R3-52, Tr3-8	
V3-3,contact 3,6	Zw3-1,contact 9	171 ohms	R3-51,R3-54, R3-55,L3-3, L3-4	
Zw3-1,contact 7	Zw3-1,contact 9	387 kilohms	R3-28,R3-29, R3-30,R3-31, R3-32,R3-26 R3-27,R3-22	
V3-4,contact 2,5	Zw3-1,contact 7	10 "	R3-57,Tr3-6	
V3-4,contact 1,4	Zw3-1,contact 4	22 "	R3-56,Tr3-6	
V3-4,contact 3,6	Zw3-1,contact 9	100 ohms	R3-53	
V3-5,contact 1,4	Zw3-4,contact 4	22 kilohms	R3-1,Tr3-7	
V3-5,contact 2,5	Zw3-1,contact 7	10 "	R3-57,R3-37 Tr3-7	
V3-5,contact 3,6	Zw3-1,contact 9	260 ohms	R3-3,R3-58	

Range mechanism unit

V4-1,contact 1	Zw4-3,contact 10	100 kilohms	R4-1	
V4-1,contact 3	Zw4-3,contact 10	3.9 "	R4-3	
V4-1,contact 6	Zw4-3,contact 10	1 "	R4-5,Tr4-1	
V4-1,contact 4	Zw4-3,contact 10	470 "	R4-4	
V4-1,contact 2	Zw4-3,contact 6	151 "	R4-2,R4-19	
V4-2,contact 4	Zw4-3,contact 10	1 megohm	R4-17	
V4-2,contact 5,3	Zw4-3,c ntact 10	150 ohms	R4-18	
V4-2,contact 6	Zw4-3,contact 6	48 kilohms	R4-16,R4-19	
V4-2,contact 8	Zw4-3,contact 6	21.4 "	R4-13,R4-14, R4-15,R4-19	R4-23 turned fully clockwise
Zw4-3,contact 6	R4-21,contact 2	2.36 "	R4-22,R4-27, R4-23	R4-23 turned fully clockwise
R4-21,contact 2	Zw4-3,contact 10	6.5 "	R4-24,A,B R4-21,R4-25 R4-26	R4-23 and R4-25 turned fully clockwise
Zw4-4,contact 1	Zw4-3,contact 10	100 ohms	M4-2	
Zw4-4,contact 16	M4-2,contact 3	100 "	M4-2	M4-4 set at AUTOMATIC
G4-1	Zw4-3,contact 10	0-10 kilohms	R4-20	R4-20 in extreme in extreme left and right positions

Power pack of range measuring and plan position indicator systems

Tr5-3,contact 5	Zw5-4	432 kilohms	R5-37-R5-48	
Zw5-4	Zw5-2,contact 1	6.7 megohms	R5-50-R5-61	
[illegible]5-2,contact 4	V5-3,contact 4	6.5 ohms	Tr5-2	
V5-11,contact 4	V5-11,contact 6	6.5 "	Tr5-2	
V5-2,contact 2	V5-4,contact 6	21 "	Dr5-1	
V5-4,contact 6	V5-4,contact 1	3 kilohms	R5-62	
V5-8,contact 8	V5-4,contact 2	1.5 "	R5-25	
V5-8,contact 8	V5-6,contact 2	1.5 "	R5-27	
V5-8,contact 8	V5-7,contact 2	1.5 "	R5-28	

V5-8,contact 8	V5-5,contact 2	1.5 kilohms	R5-26	
V5-8,contact 8	V5-7,contact 6	100 "	R5-30	
V5-7,contact 1	V5-8,contact 6	39 "	R5-31	
V5-7,contact 1	V5-8,contact 4	31 "	R5-32	R5-33 turned fully counter-clockwise
V5-7,contact 1	V5-8,contact 4	46.5 "	R5-32,R5-33	R5-33 turned fully clockwise
V5-7,contact 1	Zw5-2,contact 1	41.5 "	R5-32-R5-36, R5-62,I5-1, R5-65	
V5-8,contact 6	V5-8,contact 5	39 "	R5-29	
V5-1 cap	Zw5-1	160 "	R5-1-R5-4	
Zw5-1	Zw5-2,contact 1	2.83 megohms	R5-5-R5-18, R5-64	
Zw5-2,contact 2	Zw5-2,contact 1	10 kilohms	R5-64	
Zw5-2,contact 12	Zw5-2,contact 1	20 "	R5-17,R5-64	R5-18 turned fully counter-clockwise
Zw5-2,contact 12	Zw5-2,contact 1	67 "	R5-17,R5-18, R5-64	R5-18 turned fully clockwise
Zw5-2,contact 15	Zw5-2,contact 1	190 "	R5-15,R5-16, R5-17,R5-64	R5-18 turned fully counter-clockwise
Zw5-2,contact 14	Zw5-2,contact 1	30 "	R5-16,R5-17, R5-64,R5-18	R5-18 turned fully counter-clockwise
Zw5-3,contact 13	Zw5-2,contact 1	30 "	R5-16,R5-17, R5-64,R5-18	R5-18 turned fully counter-clockwise
Zw5-3,contact 5	Zw5-2,contact 1	10 "	R5-36	
Zw5-3,contact 10	Zw5-2,contact 1	not less than 50 megohms	insulation resistance	
Zw5-2,contact 13	Zw5-2,contact 1	"	"	

Automatic tracking unit

G6-1	G6-5	33 kilohms	R6-2	
G6-4	G6-5	500 ohms	R6-12	R6-12 turned fully clockwise
G6-6	G6-5	84 kilohms	R6-16,R6-2	
G6-7	G6-5	84 "	R6-17,R6-2	
V6-1,contact 2	G6-5	135 "	D16-1,R6-1, R6-2	
V6-1,contact 8	G6-5	135 "	D16-1,R6-1 R6-2	
V6-1,contact 4	G6-5	28.5 ohms	Tr6-1	
V6-1,contact 6	G6-5	26.3 "	Tr6-1	
V6-2,contact 2	V6-2,contact 7	0	Tr6-1	
V6-2,contact 3	G6-5	1 megohm	R6-6	
V6-2,contact 5	G6-5	1 "	R6-6	
V6-2,contact 4	G6-5	10.7 kilohms	R6-5,R6-4	
V6-2,contact 8	G6-5	10.7 "	R6-5,R6-4	
V6-3,contact 2	V6-3,contact 7	0	Tr6-1	
V6-3,contact 8	G6-5	143 "	Tr6-2,R6-22, R6-1,I6-1, R6-23,R6-2	
V6-3,contact 4	G6-5	1 megohm	R6-6	R6-6 turned fully clockwise
V6-3,contact 5	G6-5	0		
V6-3,contact 3	G6-5	0		
V6-4,contact 7	V6-4,contact 8	0	Tr6-1	
V6-4,contact 1	G6-5	110 kilohms	R6-10,R6-9,	R6-9 in mid position
V6-4,contact 4	G6-5	110 "	R6-11,R6-9	R6-9 in mid position
V6-4,contact 3	G6-5	500 ohms	R6-12	R6-12 turned fully clockwise
V6-4,contact 6	G6-5	500 "	R6-12	R6-12 turned fully clockwise

V6-4,contact 2	G6-5	164 kilohms	R6-15, R6-14, R6-20,R6-21, R6-1,R6-2	
V6-4,contact 5	G6-5	164 "	R6-13,R6-14, R6-20,R6-21, R6-2,R6-1	
V6-5,contact 2	G6-5	0		
V6-5,contact 5	G6-5	153 "	R6-18,R6-19, R6-1,R6-2	
Zw6-1,contact 6	Zw6-1,contact 7	540 ohms	P6-2	
Zw6-1,contact 2	Zw6-1,contact 4	102 kilohms	R6-16,R6-17	
Zw6-1,contact 1	G6-5	33 "	R6-2	
Zw6-1,contact 9	Zw6-1,contact 11	0	Tr6-1	
Zw6-2,contact 10	Zw6-2,contact 6	22 ohms	M6-1,M6-2,Tr6-3	
Zw6-2,contact 15	Zw6-2,contact 13	100 "	M6-1	
Zw6-2,contact 13	Zw6-2,contact 12	100 "	M6-1	
Zw6-2,contact 15	Zw6-2,contact 12	100 "	M6-1	
Zw6-2,contact 15	Zw6-2,contact 2	100 "	M6-2	
Zw6-2,contact 2	Zw6-2,contact 4	100 "	M6-2	
G6-1	G6-5	not less than 50. megohms	insulation resistance	Unsolder R6-2
V6-2,contact 3 or 5	G6-9	0		

Automatic range-finder unit

V7-1,contact 1,3	G7-8	0		
V7-1,contact 4	G7-8	146.5 ohms	R7-1,R7-2,R7-7, L7-2-L7-10	
V7-1,contact 5	G7-8	10 kilohms	R7-6	
V7-1,contact 6	Zw7-1,contact 6	28.2 "	R7-6,R7-3,R7-4, R7-9,R7-10,R7-12 R7-85,R7-86,R7-88	
V7-1,contact 8	Zw7-1,contact 6	100 "	R7-5	
V7-2,contact 1,3	G7-8	0		
V7-2,contact 4	G7-8	150 ohms	R7-7,R7-8,R7-1, L7-2-L7-10	
V7-2,contact 5	G7-8	10 kilohms	R7-12	
V7-2,contact 6	Zw7-1,contact 6	28.2 "	R7-6,R7-3,R7-4, R7-9,R7-10,R7-12, R7-85,R7-86,R7-88	
V7-2,contact 8	Zw7-1,contact 6	100 "	R7-11	
V7-3,contact 4,8	0			
V7-3,contact 3	V7-4,contact 4	2.4 "	R7-13	
V7-3,contact 5	V7-5,contact 4	2.4 "	R7-24	
V7-4,contact 8	Zw7-1,contact 6	16.21-19.51 kilohms	R7-14,R7-17,R7-15, R7-18,R7-16	R7-17 turned to extreme left and right position
V7-5,contact 8	Zw7-1,contact 6	16.21-19.51 kilohms	R7-17,R7-21,R7-18, R7-22,R7-23	R7-17 turned to extreme left and right position
V7-5,contact 1, 3, 5	G7-8	0		
V7-5,contact 6	V7-4,contact 6	0		
V7-6,contact 1,3	G7-8	0		
V7-6,contact 5	G7-8	2 kilohms	R7-25	
V7-6,contact 6,8	Zw7-1,contact 6	0		
V7-6,contact 4	G7-8	200.1 "	R7-26,R7-27	
V7-7,contact 1, 3, 5	G7-8	0		
V7-7,contact 6,8	V7-12,contact 5	4.1 "	R7-28,R7-29	
V7-7,contact 4	G7-8	20.0 "	R7-30,R7-31	
V7-8,contact 2	Zw7-1,contact 6	15.7 "	R7-32,R7-33,R7-34	

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V7-8, contact 3	G7-8	0.47-2.67 kilohms	R7-35, R7-36	R7-36 turned to extreme left or right position
V7-8, contact 4,5	G7-8	0		
V7-9, contact 8	G7-8	250 ohms	R7-40, R7-41, R7-42, R7-43	
V7-9, contact 5	V7-11, contact 4	910 kilohms	R7-47	
V7-9, contact 4	Zw7-1, contact 6	0		
V7-9, contact 5	G7-8	1.438 megohms	R7-44, R7-47, R7-46	
V7-10, contact 5	G7-8	1.42 "	R7-44, R7-45	
V7-10, contact 8	G7-8	250 ohms	R7-40, R7-41, R7-42, R7-43	
V7-10, contact 4	Zw7-1, contact 6	0		
V7-11, contact 2	Zw7-1, contact 6	250 kilohms	R7-50, R7-51	
V7-11, contact 5	Zw7-1, contact 6	250 "	R7-49, R7-50	
V7-11, contact 4	V7-10, contact 5	928 "	R7-45, R7-46	
V7-11, contact 3,6	G7-8	1 kilohm	R7-53	
V7-11, contact 1	R7-56, middle contact	200 kilohms	R7-52	
V7-13, contact 1, 3,5	G7-8	0		
V7-13, contact 6	Zw7-1, contact 6	13.25 "	R7-59, R7-60, Tr7-2	
V7-13, contact 4	G7-8	3 kilohms - 2.2 megohms	R7-63, R7-65, Tr7-2	R7-63 turned to extreme left or right position
V7-14, contact 1, 2,4,5	G7-8	4.2 megohms	R7-63, R7-64	
V7-14, contact 3, 6	G7-8	20 kilohms	R7-61, R7-62	
V7-15, contact 1	V7-16, contact 2	1.2 megohms	R7-82	
V7-15, contact 2	Zw7-1, contact 6	1 kilohm	R7-78	
V7-15, contact 4	V7-16, contact 5	1.2 megohm	R7-73	
V7-15, contact 5	Zw7-1, contact 6	1 kilohm	R7-77	
V7-15, contact 3	G7-8	63.2 kilohms	R7-76, R7-72, R7-68, R7-71, R7-75	
V7-15, contact 6	G7-8	63.2 "	R7-75, R7-71, R7-68, R7-72, R7-76	
V7-16, contact 1	V7-17, contact 4	1.2 megohm	R7-87	
V7-16, contact 5	Zw7-1, contact 6	0.1-0.2 "	R7-81, R7-80	R7-80 turned to extreme left or right position
V7-16, contact 3,	G7-8	39 kilohms	R7-84	
V7-16, 6ontact 4	V7-17, contact 8	1.2 megohms	R7-95	
V7-16, contact 2	Zw7-1, contact 6	0.1-0.2 "	R7-95, R7-80	R7-80 set fully clockwise and counter-clockwise
V7-17, contact 3	G7-8	5 kilohms	R7-89, R7-25	
V7-17, contact 5	G7-8	5 "	R7-90, R7-25	
V7-17, contact 4	V7-17, contact 8	4.6 megohms	R7-91, R7-92, R7-93	

Range unit

V8-1, contact 4	Zw8-1, contact 10	2.2 megohms	R8-1	
V8-1, contact 5	Zw8-1, contact 10	590 ohms	R8-2, L8-1	
V8-1, contact 6	G8-14	100-570 kilohms	R8-3, R8-36	R8-36 set fully clockwise and counter-clockwise

V8-1, contact 8	G8-14	16.4 ohms	L8-2	
V8-2, contact 1	Zw8-1, contact 10	47 kilohms	R8-4	
V8-2, contact 2	G8-14	22 "	R8-5A	
V8-2, contact 5	G8-14	22 "	R8-5B	
V8-2, contact 4	Zw8-1, contact 10	130 "	R8-7	
V8-3, contact 1	Zw8-1, contact 10	51 "	R8-8	
V8-3, contact 2	G8-14	22 "	R8-9A	
V8-3, contact 5	G8-14	22 "	R8-9B	
V8-3, contact 4	Zw8-1, contact 10	62-109 "	R8-11, R8-12	R8-12 set fully clockwise and counter-clockwise
V8-4, contact 1	Zw8-1, contact 10	51 "	R8-17	
V8-4, contact 2	G8-14	22 "	R8-13A	
V8-4, contact 5	G8-14	22 "	R8-13B	
V8-4, contact 4	Zw8-1, contact 10	24-71 "	R8-15, R8-16	R8-16 set fully clockwise and counter-clockwise
V8-5, contact 5	Zw8-1, contact 10	840 "	R8-94, R8-22	
V8-5, contact 8	Zw8-1, contact 10	1 "	R8-20	
V8-6, contact 1	Zw8-1, contact 10	100 "	R8-23	
V8-6, contact 3	Zw8-1, contact 10	10 "	R8-24	
V8-6, contact 6	Zw8-1, contact 10	10 "	R8-25	
V8-6, contact 4	Zw8-1, contact 10	1 megohm	R8-26	
V8-7, contact 1	Zw8-1, contact 10	27-90 kilohms	R8029, R8-27, R8-18 R8-21, R8-33, R8-45 A,B, R8-39, R8-40 R8-28, R8-70, R8-89 R8-78, R8-81	R8-27 set fully clockwise and counter-clockwise
V8-7, contact 2	G8-14	5.6 kilohms	R8-35	
V8-7, contact 5	G8-14	5 "	R8-32 A,B	
V8-7, contact 4	G8-14	3.3 megohms	R8-34	
V8-7, contact 6,3	Zw8-1, contact 10	2.55 kilohms	R8-30, R8-31	
V8-8, contact 1	Zw8-1, contact 10	54 "	R8-39, R8-40, R8-18 R8-21, R8-27, R8-28 R8-33, R8-45 A,B R8-70, R8-78, R8-81 R8-89	
V8-8, contact 6	Zw8-1, contact 10	7.8 "	R8-24, A,B	
V8-8, contact 4	Zw8-1, contact 10	470 "	R8-43	
V8-8, contact 3	Zw8-1, contact 10	10 "	R8-41	
V8-9, contact 4	G8-14	560 "	R8-55 A	
V8-9, contact 1,5	Zw8-1, contact 10	0		
V8-9, contact 8	G8-14	19.5 "	R8-69, R8-93	
V8-9, contact 3	Zw8-1, contact 10	22 "	R8-6	
V8-10, contact 8	G8-14	56 "	R8-59	
V8-10, contact 6	G8-14	27 "	R8-95	
V8-10, contact 4	G8-14	560 "	R8-55 B	
V8-10, contact 3	V8-9, contact 8	270 "	R8-14	
V8-10, contact 3	Zw8-1, contact 7	270 "	R8-10	
V8-11, contact 8	G8-14	4.36 "	R8-33, R8-45 A,B R8-39, R8-40, R8-18 R8-21, R8-27, R8-28 R8-70, R8-78, R8-81 R8-89	
V8-11, contact 8	Zw8-1, contact 10	14.9 "	R8-33, R8-45 A,B R8-18, R8-21, R8-27 R8-28, R8-39, R8-40 R8-70, R8-78, R8-81 R8-89	
V8-11, contact 4	Tr8-4, contact 1	0		
V8-11, contact 5	Zw8-2, contact 12	120 "	R8-49	
V8-12, contact 8	G8-14	10 "	R8-54 A,B R8-56 A,B	

V8-12, contact 4	Zw8-1, contact 10	100 kilohms	R8-52	
V8-12, contact 5,3	Zw8-1, contact 10	150 ohms	R8-53	
V8-12, contact 6	G8-14	16.5 kilohms	R8-58 A,B	
V8-13, contact 8	G8-14	5.1 "	R8-60	
V8-13, contact 6	G8-11	33 "	R8-62	
V8-13, contact 4	Zw8-1, contact 5	220 "	R8-61	
V8-14, contact 1	Zw8-1, contact 10	27 "	R8-67	
V8-14, contact 2	G8-14	7.5 "	R8-63	
V8-14, contact 5	G8-14	7.5 "	R8-64, R8-65	
V8-14, contact 4	G8-14	3.3 megohms	R8-66	
V8-14, contact 3,6	Zw8-1, contact 10	1.5 kilohms	R8-68	
V8-15, contact 1	Zw8-1, contact 10	471.5 "	R8-77, R8-78, R8-70 R8-81, R8-89, R8-18 R8-21, R8-27, R8-28 R8-33, R8-45 A,B R8-39, R8-40	R8-77 turned fully clockwise
V8-15, contact 2	G8-14	6 "	R8-71, R8-72, R8-73 R8-74, R8-75	
V8-15, contact 5	G8-14	6.3 "	R8-76, R8-71	
V8-15, contact 4	G8-11	5.1 megohms	R8-79	
V8-16, contact 1	Zw8-1, contact 10	472.7 - 2.7 kilohms	R8-88, R8-89, R8-81 R8-70, R8-78, R8-33 R8-45 A,B, R8-18 R8-21, R8-39, R8-40 R8-27, R8-28	R8-88 turned fully clockwise and counter- clockwise
V8-16, contact 2	G8-14	6 "	R8-82, R8-83, R8-84 R8-85, R8-86	
V8-16, contact 5	G8-14	3.8 "	R8-51, R8-87	
V8-16, contact 4	Zw8-1, contact 9	5.1 megohms	R8-90	
8-14	Zw8-1, contact 10	15.8 kilohms	R8-18, R8-21, R8-27 R8-28, R8-33, R8-45 A,B R8-39, R8-40 R8-70, R8-78, R8-81, R8-89	
V8-17, contact 8	G8-14	11 "	R8-97 A,B	
V8-17, contact 4	G8-14	2 megohms	R8-96	
V8-17, contact 6	G8-14	39 kilohms	R8-47	
V8-17, contact 1,3	Zw8-1, contact 10	0		
V8-9, contact 6	G8-14	56 "	R8-50	

Power pack of range measuring system

V9-1, contact 8	Zw9-1, contact 9	103 ohms	D1-1	
V9-4, contact 2	Zw9-2, contact 4	15.7 "	R9-1, R9-2, R9-3	
V9-5, contact 8	Zw9-1, contact 3	80 "	D19-2	
Zw9-1, contact 1	Zw9-1, contact 3	Not less than 50 megohms	Insulation resistance	
Zw9-1, contact 13	Zw9-1, contact 3	" "	" "	

Azimuth and elevation tracking unit

G10-1	G10-3	20 kilohms	R10-5	
G10-2	G10-3	20 "	R10-6	
G10-3	Chassis	0		
G10-4	G10-3	220 "	R10-7, R10-20, D110-1, R10-5	
G10-5	G10-3	220 "	R10-9, R10-21, R10-6, D110-2	
G10-6	G10-3	40 "	R10-40, R10-41	
G10-7	G10-3	40 "	R10-13, R10-14 R10-15, R10-16 R10-38, R10-88 R10-12, R10-62	R10-14, R10-15 set fully clockwise

				R10-16,R10-39 R10-88,R10-12 R10-62,R10-89 R10-33,R10-38	set fully clockwise
G10-11	G10-3	3.1	"	R10-14,R10-15 R10-16,R10-39 R10-88,R10-12 R10-89,R10-33 R10-62,R10-38	R10-14,R10-15 turned fully counter- clockwise
G10-12	G10-3	2.2	"	R10-16	
G10-13	G10-3	3.3	"	R10-14,R10-38 R10-12,R10-62 R10-88,R10-33 R10-15,R10-89 R10-16,R10-39	R10-14,R10-15 turned fully counter- clockwise
G10-14	G10-3	4.2	"	R10-33,R10-62 R10-88,R10-38 R10-14,R10-16 R10-12,R10-89 R10-15,R10-39	R10-14,R10-15, R10-33 turned fully clockwise
G10-14	G10-3	6.3	"	R10-33,R10-15 R10-39,R10-14 R10-38,R10-12 R10-89,R10-88 R10-16,R10-62	R10-14,R10-15 set fully clockwise; R10-33 set fully counter- clockwise
G10-51	G10-3	20	"	R10-55	
G10-52	G10-3	20	"	R10-56	
G10-53	G10-3	0			
G10-54	G10-3	220	"	R10-57,R10-70 D10-51,R10-55	
G10-55	G10-3	220	"	R10-59,R10-71 D10-52,R10-56	
V10-1,contact 2	G10-3	51	"	R10-29,R10-30 R10-13,R10-14 R10-33,R10-12 R10-38,R10-88 R10-39,R10-89 R10-62,R10-16 R10-15	R10-14,R10-15, R10-33 set fully clockwise
V10-1,contact 5	G10-3	51	"	R10-14,R10-38 R10-15,R10-39 R10-27,R10-12 R10-28,R10-13 R10-16,R10-33 R10-88,R10-62 R10-89	R10-14,R10-15, R10-33 set fully clockwise
V10-2,contact 2	G10-3	51	"	R10-29,R10-89 R10-39,R10-62 R10-33,R10-13 R10-15,R10-12 R10-14,R10-88 R10-38,R10-16	
V10-2,contact 5	G10-3	51	"	R10-27,R10-88 R10-13,R10-89 R10-38,R10-28 R10-39,R10-14 R10-16,R10-15 R10-12,R10-62 R10-33	R10-14,R10-15, R10-33 set fully clockwise
V10-3,contact 2	G10-3	51	"	R10-29,R10-30 R10-39,R10-16 R10-13,R10-62 R10-33,R10-89 R10-12,R10-14	R10-14,R10-15, R10-33 set fully clockwise

[illegible]	[illegible]	[illegible]		R10-89,R10-13 R10-16,R10-62 R10-33,R10-27 R10-15,R10-12 R10-14,R10-88 R10-38	R10-33 set fully clockwise
V10-51,contact 2	G10-3	51	"	R10-13,R10-89 R10-39,R10-80 R10-16,R10-62 R10-33,R10-12 R10-79,R10-38 R10-88,R10-14 R10-15	R10-14,R10-15, R10-33 set fully clockwise
V10-51,contact 5	G10-3	51	"	R10-12,R10-38 R10-77,R10-78 R10-62,R10-89 R10-13,R10-16 R10-15,R10-14 R10-39,R10-88 R10-33	R10-14,R10-15, R10-33 set fully clockwise
V10-52,contact 2	G10-3	51	"	R10-13,R10-88 R10-80,R10-38 R10-89,R10-33 R10-12,R10-14 R10-62,R10-16 R10-79,R10-39 R10-15	R10-14,R10-15, R10-33 set fully clockwise
V10-52,contact 5	G10-3	51	"	R10-13,R10-14 R10-38,R10-77 R10-12,R10-89 R10-15,R10-78 R10-16,R10-88 R10-39,R10-62 R10-33	R10-14,R10-15, R10-33 set fully clockwise
V10-53,contact 2	G10-3	51	"	R10-13,R10-14 R10-38,R10-79 R10-12,R10-39 R10-15,R10-80 R10-16,R10-33 R10-88,R10-62 R10-89	R10-14,R10-15 set fully clockwise
V10-53,contact 5	G10-3	51	"	R10-13,R10-14 R10-38,R10-77 R10-12,R10-39 R10-15,R10-78 R10-16,R10-33 R10-88,R10-62 R10-89	
V10-1,contact 3	G10-3	20	"	R10-5	
V10-1,contact 6	G10-3	20	"	R10-5	
V10-2,contact 3 or 6	G10-3	20	"	R10-6	
V10-51,contact 3 or 6	G10-3	20	"	R10-55	
V10-52,contact 3 or 6	G10-3	20	"	R10-56	
V10-3,contact 3 or 6	G110-3	0			
V10-53,contact 3 or 6		0			
V10-4,contact 4	G10-3	38	"	R10-10,R10-35 R10-13,R10-14 R10-38,R10-12 R10-39,R10-15 R10-16,R10-88	R10-14,R10-15 set fully clockwise

V10-4, contact 5	G10-3	220 kilohms	R10-7, R10-20 R10-5, D10-1	
V10-4, contact 8	G10-3	2 "	R10-17, R10-8	R10-8 set fully clockwise
V10-4, contact 8	G10-3	1 "	R10-17, R10-8	R10-8 set fully counter-clockwise
V10-5, contact 4	G10-3	38 "	R10-11, R10-36 R10-13, R10-14 R10-38, R10-12 R10-39, R10-16 R10-15, R10-62 R10-88, R10-89	R10-14, R10-15 set fully clockwise
V10-5, contact 5	G10-3	220 "	R10-9, R10-21 R10-6, D10-2	
V10-5, contact 8	G10-3	2 "	R10-8, R10-17	R10-8 set fully clockwise
V10-5, contact 8	G10-3	1 "	R10-8, R10-17	R10-8 set fully counter-clockwise
V10-54, contact 4	G10-3	38 "	R10-60, R10-85 R10-13, R10-14 R10-38, R10-12 R10-39, R10-16 R10-15, R10-62 R10-88, R10-89	R10-14, R10-15 set fully clockwise
V10-54, contact 8	G10-3	220 "	R10-57, R10-70 D10-51, R10-55	
V10-54, contact 8	G10-3	2 "	R10-58, R10-67	R10-58 set fully clockwise
V10-54, contact 8	G10-3	1 "	R10-58, R10-67	R10-58 set fully counter-clockwise
V10-55, contact 4	G10-3	38 "	R10-61, R10-86 R10-13, R10-14 R10-33, R10-12 R10-39, R10-16 R10-62, R10-88 R10-89, R10-15	R10-14, R10-15 set fully clockwise
V10-55, contact 5	G10-3	220 "	R10-59, R10-71 R10-56, D10-52	
V10-55, contact 8	G10-3	2 "	R10-67, R10-58	R10-58 set fully clockwise
V10-6, contact 1	G10-3	1-0.51 megohms	R10-38, R10-14 R10-33, R10-18 R10-24, R10-39 R10-16, R10-15 R10-12, R10-62 R10-89, R10-88	R10-24 set fully clockwise and counter-clockwise
V10-6, contact 2	G10-3	38 kilohms	R10-10, R10-13 R10-14, R10-35 R10-39, R10-15 R10-16, R10-88 R10-62, R10-89	R10-14, R10-15 set fully clockwise
V10-6, contact 3 or 6	G10-3	1.8 "	R10-37, R10-19	
V10-6, contact 5	G10-3	38 "	R10-11, R10-36 R10-13, R10-14 R10-38, R10-12 R10-39, R10-15 R10-16, R10-62 R10-88, R10-89	R10-14, R10-15 set fully clockwise
V10-6, contact 4	G10-3	2.8-3.2 "	R10-12, R10-39 R10-15, R10-16 R10-88, R10-62 R10-89, R10-38 R10-14	R10-14, R10-15 set fully counter clockwise; R10-12 set fully clockwise and

V10-7, contact 1	G10-3	1-0.51 megohm	R10-62, R10-18 R10-24, R10-15 R10-16, R10-33 R10-14, R10-38 R10-39, R10-12 R10-88, R10-89	R10-24 set fully clockwise and counter-clockwise
V10-7, contact 2	G10-3	38 kilohms	R10-10, R10-14 R10-35, R10-13 R10-38, R10-12 R10-39, R10-15 R10-16, R10-88 R10-62, R10-89	R10-14, R10-15 set fully clockwise
V10-7, contact 3 or 6	G10-3	1.8 "	R10-37, R10-19	
V10-7, contact 5	G10-3	38 "	R10-11, R10-36 R10-13, R10-14 R10-38, R10-12 R10-39, R10-15 R10-16, R10-88 R10-89, R10-62	R10-14, R10-15 set fully clockwise
V10-7, contact 4	G10-3	2.8-3.2 "	R10-12, R10-39 R10-15, R10-38 R10-14, R10-88 R10-62, R10-89 R10-16	R10-14, R10-15 set fully counter-clockwise; R10-12 set fully clockwise and counter-clockwise
V10-8, contact 3	G10-3	2.2 "	R10-16	
V10-8, contact 4 or 5	G10-3	1 megohm	R10-39, R10-12 R10-38, R10-18 R10-24, R10-15 R10-16, R10-33 R10-14, R10-62 R10-88, R10-89	R10-24 set fully clockwise
V10-8, contact 8	G10-3	3.2 kilohms	R10-16, R10-14 R10-38, R10-12 R10-39, R10-15 R10-62, R10-88 R10-89, R10-33	R10-14, R10-15 set fully counter-clockwise
V10-9, contact 3	G10-3	6.3 "	R10-33, R10-14 R10-38, R10-12 R10-39, R10-15 R10-16, R10-88 R10-62, R10-89	R10-14, R10-15 set fully clockwise; R10-33 set fully counter-clockwise
V10-9, contact 2	G10-3	220 "	R10-7, R10-20 D10-1, R10-5	
V10-9, contact 5	G10-3	220 "	R10-9, R10-21 D10-2, R10-6	
V10-56, contact 1	G10-3	1-0.51 megohm	R10-68, R10-74 R10-15, R10-16 R10-33, R10-14 R10-38, R10-12 R10-39, R10-88 R10-62, R10-89	R10-74 set fully clockwise and counter-clockwise
V10-57, contact 1	G10-3	1-0.51 "	R10-68, R10-74 R10-15, R10-16 R10-33, R10-14 R10-38, R10-12 R10-39, R10-88 R10-62, R10-89	R10-74 set fully clockwise and counter-clockwise

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V10-56, contact 2	G10-3	38 kilohms	R10-60, R10-85 R10-13, R10-14 R10-38, R10-12 R10-39, R10-15 R10-16, R10-88 R10-62, R10-89	R10-14, R10-15 set fully clockwise
V10-56, contact 3 or 6	G10-3	1.8 "	R10-69, R10-87	
V10-56, contact 4	G10-3	2.8-3.2 "	R10-62, R10-89 R10-14, R10-15 R10-16, R10-38 R10-39, R10-12 R10-88	R10-14, R10-15 set fully counter- clockwise; R10-62 set fully clockwise and counter- clockwise
V10-57, contact 2	G10-3	38 "	R10-60, R10-85 R10-13, R10-14 R10-38, R10-12 R10-39, R10-15 R10-16, R10-88 R10-62, R10-89	R10-14, R10-15 set fully clockwise
V10-57, contact 3 or 6	G10-3	1.8 "	R10-69, R10-87	
V10-57, contact 5	G10-3	38 "	R10-61, R10-86 R10-13, R10-14 R10-38, R10-12 R10-39, R10-15 R10-16, R10-88 R10-62, R10-89	R10-14, R10-15 set fully clockwise
V10-57, contact 4	G10-3	2.8-3.2 "	R10-62, R10-89 R10-14, R10-12 R10-16, R10-15 R10-38, R10-39 R10-88	R10-14, R10-15 set fully counter- clockwise; R10-62 set fully clockwise and counter- clockwise
V10-58, contact 3	G10-3	2.2 "	R10-16	
V10-58, contact 4 or 5	G10-3	1 megohm	R10-68, R10-74 R10-15, R10-16 R10-33, R10-14 R10-38, R10-12 R10-89, R10-39 R10-88, R10-62	R10-74 set fully counter- clockwise
V10-58, contact 8	G10-3	3.2 kilohms	R10-14, R10-38 R10-12, R10-39 R10-15, R10-16 R10-88, R10-62 R10-89	R10-14, R10-15 set fully counter- clockwise
V10-59, contact 3 or 6	G10-3	6.3 "	R10-33, R10-14 R10-38, R10-12 R10-15, R10-16 R10-39, R10-88 R10-62, R10-89	R10-14, R10-15 set fully clockwise; R10-33 set fully counter- clockwise
V10-59, contact 2	G10-3	220 "	R10-57, R10-70 R10-55, D10-51	
V10-59, contact 5	G10-3	220 "	R10-59, R10-71 R10-56, D10-52	

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Zw10-2,contact 19	G10-3	40 kilohms	R10-40,R10-39 R10-16,R10-88 R10-14,R10-89 R10-15,R10-62 R10-12,R10-38 R10-33,R10-13	R10-14,R10-15, R10-33 set fully clockwise
Zw10-2,contact 20	G10-3	40 "	R10-41,R10-39 R10-13,R10-88 R10-14,R10-89 R10-15,R10-62 R10-12,R10-16 R10-38,R10-33	R10-14,R10-15, R10-33 set fully clockwise
G10-56	G10-3	Not less than 50 megohms	Insulation resistance	
G10-57	G10-3	"	"	
Zw10-1,contact 2	G10-3	"	"	
Zw10-1,contact 3	G10-3	"	"	
Zw10-1,contact 4	G10-3	"	"	
Zw10-1,contact 5	G10-3	"	"	
Zw10-1,contact 6	G10-3	"	"	
Zw10-1,contact 8	G10-3	"	"	
Zw10-1,contact 13	G10-3	"	"	
Zw10-1,contact 14	G10-3	"	"	
Zw10-1,contact 17	G10-3	"	"	
Zw10-1,contact 18	G10-3	"	"	
Zw10-1,contact 22	G10-3	"	"	
Zw10-2,contact 1	G10-3	"	"	
Zw10-2,contact 2	G10-3	"	"	
Zw10-2,contact 4	G10-3	"	"	
Zw10-2,contact 11	G10-3	"	"	
Zw10-2,contact 12	G10-3	"	"	
Zw10-2,contact 13	G10-3	"	"	
Zw10-2,contact 14	G10-3	"	"	
Zw10-2,contact 15	G10-3	"	"	
Zw10-2,contact 16	G10-3	"	"	
Zw10-2,contact 17	G10-3	"	"	

Plan position indicator unit

V11-1,contact 1	Zw11-2,contact 2	220 kilohms	R11-1	
V11-1,contact 4	Zw11-2,contact 2	220 "	R11-3	
V11-1,contact 5	Zw11-1,contact 5	220 "	R11-4	
V11-1,contact 2	Zw11-1,contact 5	100 "	R11-2	
V11-1,contact 3	Zw11-2,contact 2	0		
V11-1,contact 6	Zw11-1,contact 4	0		
V11-2,contact 1	Zw11-2,contact 2	100 "	R11-53	R11-5 set fully counter- clockwise
V11-2,contact 1	Zw11-2,contact 2	570 "	R11-53,R11-5	R11-5 set fully clockwise
V11-2,contact 4	Zw11-2,contact 2	4.7 megohms	R11-7	
V11-2,contact 3,6	Zw11-2,contact 2	0		
V11-2,contact 2	Zw11-1,contact 5	21 kilohms	R11-6,R11-8,R11-10	
V11-2,contact 5	Zw11-1,contact 5	21 "	R11-10,R11-9,R11-8	
V11-2,contact 5	G11-1	0		
V11-3,contact 5	V11-4,contact 5	1 megohm	R11-18	
V11-3,contact 3	Zw11-2,contact 2	0		
V11-3,contact 2	Zw11-1,contact 7	32.5 kilohms	R11-11,R11-13 R11-14,R11-15	
V11-3,contact 1	Zw11-1,contact 5	4.7 megohms	R11-12	
V11-3,contact 4	V11-3,contact 5	0		
V11-3,contact 6	V11-4,contact 5	0		
V11-3,contact 5	Zw11-2,contact 2	0		

V11-3,contact 5	Zw11-2,contact 2	470 kilohms	R11-19	R11-19 set fully clockwise; R11-19 set fully counter-clockwise
V11-4,contact 8	Zw11-2,contact 2	320 ohms	L11-2	
V11-4,contact 3	Zw11-1,contact 5	100 "	R11-17	
V11-4,contact 3	V11-4,contact 4	100 "	R11-20	
V11-5,contact 1	Zw11-2,contact 2	472.64 kilohms	R11-23,R11-22 R11-21,R11-48 R11-49,R11-50 R11-33,R11-34 R11-35,R11-36 R11-28,R11-51 L11-1	R11-23 set fully clockwise; R11-50 set fully counter-clockwise
V11-5,contact 1	Zw11-2,contact 2	2.64 "	R11-23,R11-22 R11-21,R11-48 R11-49,R11-50 R11-51,R11-28 R11-33,R11-34 R11-35,R11-36 L11-1	R11-23,R11-50 set fully counter-clockwise
V11-5,contact 2	Zw11-1,contact 5	6 "	R11-24,R11-25	
V11-5,contact 5	Zw11-1,contact 5	3.9 "	R11-26	
V11-5,contact 4	Zw11-1,contact 10	5.1 megohms	R11-27	
V11-5,contact 3,6	Zw11-2,contact 2	0		
V11-6,contact 3	Zw11-1,contact 5	15 kilohms	R11-28,R11-51 R11-48,R11-49 R11-50,R11-33 R11-34,R11-35 R11-36,R11-21 R11-22,L11-1	R11-50 set fully counter-clockwise
V11-6,contact 1	Zw11-2,contact 2	47 "	R11-62	
V11-6,contact 5	Zw11-1,contact 5	20 "	R11-30,R11-31	
V11-6,contact 4	Zw11-1,contact 5	4.7 megohms	R11-32	
V11-6,contact 3	Zw11-2,contact 2	6.8 kilohms	R11-51,R11-28 R11-48,R11-49 R11-50,R11-33 R11-34,R11-35 R11-36,R11-21 R11-22,L11-1	R11-50 set fully counter-clockwise
V11-6,contact 6	G11-5	0		
V11-6,contact 6	Zw11-2,contact 2	2.1 "	R11-36,R11-34 R11-33,R11-21 R11-22,R11-48 R11-49,R11-50 R11-51,R11-28 L11-1	R11-50 set fully counter-clockwise;R11-35 set fully clockwise
V11-6,contact 6	Zw11-2,contact 2	5.8 "	R11-36,R11-35 R11-34,R11-33 R11-21,R11-22 R11-48,R11-49 R11-50,R11-51 R11-28,L11-1	R11-50,R11-35 set fully counter-clockwise
V11-7,contact 1	Zw11-2,contact 2	180 "	R11-42	
V11-7,contact 2	Zw11-1,contact 5	6.8 "	R11-40,R11-37 R11-38,R11-39	
V11-7,contact 3,	Zw11-2,contact 2	0		
V11-7,contact 6	G11-3	0		
V11-8,contact 2	V11-8,contact 5	0		

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V11-8, contact 2,5	Zw11-1, contact 5	5.3 kilohms	R11-37, R11-38 R11-39	
V11-8, contact 4	Zw11-2, contact 2	4.3 "	R11-45, R11-46	R11-29, R11-47 set fully counter-clockwise
V11-8, contact 4	Zw11-2, contact 2	13.5 "	R11-45, R11-46 R11-29	R11-29 set fully clockwise; R11-47 set fully counter-clockwise
V11-8, contact 4		4.9 "	R11-45, R11-46 R11-47	R11-47 set fully clockwise; R11-29 set fully counter-clockwise
V11-8, contact 3	V11-8, contact 6	0		
V11-8, contact 3,6	G11-4	0		
V11-8, contact 3,6	Zw11-2, contact 2	1 "	R11-44	
V11-9, contact 7	G11-5	0		
V11-9, contact 5	G11-4	0		
V11-9, contact 3	Zw11-1, contact 5	0		
V11-10, contact 5	Zw11-1, contact 7	3 "	R11-11	
V11-10, contact 2	Zw11-1, contact 5	0		
V11-11, contact 5	Zw11-11, contact 3	0		
V11-11, contact 5	Zw11-2, contact 2	4.37 "	R11-58, R11-59 R11-2	
V11-11, contact 6	Zw11-2, contact 6	1.5 megohms	R11-55	
V11-11, contact 8	Zw11-2, contact 6	320 kilohms	R11-54, R11-56	
V11-12, contact 5	Zw11-2, contact 2	1 megohm	R11-57	
V11-12, contact 3	V11-12, contact 4	0		
V11-12, contact 3	Zw11-2, contact 8	0		
V11-12, contact 8	Zw11-2, contact 2	600 ohms	R11-60, R11-61	
Zw11-1, contact 9	Zw11-2, contact 2	1 megohm	R11-41	
Zw11-1, contact 5	Zw11-2, contact 2	9.8 kilohms	R11-21, R11-22 R11-33, R11-34 R11-35, R11-36 R11-28, R11-48 R11-49, R11-50 R11-51, L11-1	R11-50 set fully counter-clockwise
G11-3	Zw11-2, contact 2	1 megohm	R11-43	
Zw11-2, contact 11	Zw11-2, contact 12	0		
Zw11-2, contact 13	Zw11-2, contact 14	0		

Antenna control unit

Zw12-1, contact 2	Zw12-2, contact 6	100 ohms	M12-51	
Zw12-1, contact 2	Zw12-2, contact 8	100 "	M12-51	
Zw12-2, contact 6	Zw12-2, contact 8	100 "	M12-51	
Zw12-1, contact 11	Zw12-1, contact 12	100 "	M11-1	
Zw12-1, contact 11	Zw12-1, contact 9	100 "	M12-1	
Zw12-1, contact 12	Zw12-1, contact 9	100 "	M12-1	
Zw12-2, contact 9	Zw12-2, contact 10	9.2 "	Tr12-52, Tr12-3 M12-51, Tr12-2 M12-1	
Zw12-1, contact 8	Zw12-1, contact 3	0	W12-2	Switch on W12-2
Zw12-1, contact 4	Zw12-2, contact 10	260 "	E12-1, E12-51	W12-1 set at AUTOMATIC
Zw12-1, contact 4	Zw12-1, contact 1	Not less than 50 megohms	Insulation resistance	
Zw12-1, contact 9	Zw12-1, contact 1	"	"	
Zw12-1, contact 11	Zw12-1, contact 1		"	

Zw12-1, contact 12	Zw12-1, contact 1	Not less than 50 megohms	Insulation resistance	
Zw12-1, contact 15	Zw12-1, contact 1	"	"	
Zw12-2, contact 6	Zw12-1, contact 1	"	"	
Zw12-2, contact 8	Zw12-1, contact 1	"	"	
Zw12-2, contact 9	Zw12-1, contact 1	"	"	

I-F preamplifier unit

Zw22-1	Zw22-5, contact 1	100 ohms	Tr22-1, L22-1, L22-2 R22-2, R22-2, R22-3 R22-61	W22-3 set at SIGNAL
V22-1, contact 5	Zw22-5, contact 1	100 ohms - 1.1 kilohms	R22-4, R22-63	With R22-63 in extreme positions
V22-1, contact 6	G22-46	330 ohms	R22-5	
V22-1, contact 8	G22-46	330 "	L22-3, R22-5	
V22-2, contact 4	Zw22-5, contact 1	510 "	R22-6	
V22-2, contact 5	Zw22-5, contact 1	100 "	R22-7	
V22-2, contact 6	G22-46	330 "	R22-8	
V22-2, contact 8	G22-46	330 "	L22-4, R22-8	
V22-3, contact 4	Zw22-5, contact 1	510 "	R22-9	
V22-3, contact 5	Zw22-5, contact 1	100 "	R22-10	
V22-3, contact 6	G22-46	330 "	R22-11, Tr22-2	
V22-4, contact 3,5	Zw22-5, contact 1	100 kilohms	Tr22-2, L22-5, R22-13	
V22-4, contact 8	Zw22-5, contact 1	200 "	R22-14, R22-15	
V22-5, contact 4	Zw22-5, contact 1	513 "	R22-16, R22-22	
V22-5, contact 6	G22-37	390 "	R22-19	
V22-5, contact 8	G22-37	18 "	R22-18	
V22-6, contact 4,8	Zw22-5, contact 1	265 "	R22-21, R22-22 R22-59, R22-49 R22-50, R22-51 R22-55, R22-56	
V22-6, contact 3,5	Zw22-5, contact 1	2.1 megohms	R22-20, R22-21 R22-22, R22-50 R22-51, R22-59 R22-55, R22-56 R22-49	
V22-7, contact 4	Zw22-5, contact 1	3.9 megohms	R22-23, R22-20 R22-50, R22-56 R22-21, R22-22 R22-51, R22-59 R22-49, R22-55	
V22-7, contact 5	Zw22-5, contact 1	265 kilohms	R22-21, R22-22 R22-49, R22-50 R22-51, R22-55 R22-59, R22-56	
V22-7, contact 6	Zw22-5, contact 1	200 "	R22-25, R22-21 R22-22, R22-51 R22-50, R22-49 R22-55, R22-56 R22-59, R22-60 R22-58	W22-4 set at AFC
V22-7, contact 8	Zw22-5, contact 1	375 "	R22-26, R22-25 R22-24, R22-22 R22-21, R22-51 R22-50, R22-49 R22-60, R22-58 R22-59, R22-55 R22-56	W22-3 set at AFC

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Zw22-2	Zw22-5,contact 1	100 ohms	L22-7,L22-8,L22-6 R22-61	W22-3 set at AFC
V22-8,contact 2	Zw22-5,contact 1	200 "	R22-31	
V22-8,contact 5,6	V22-12,contact 5	1.15 kilohms	L22-11,R22-32 R22-36	
V22-9,contact 2	Zw22-5,contact 1	200 ohms	R22-33,L22-12 L22-10,L22-9	
V22-9,contact 5,6	V22-12,contact 5	1.15 kilohms	L22-13,R22-34 R22-36	
V22-10,contact 4	Zw22-5,contact 1	680 ohms	R22-35	
V22-10,contact 5	Zw22-5,contact 1	100 "	R22-37	
V22-10,contact 6	V22-12,contact 5	330 "	R22-49	
V22-10,contact 8	V22-12,contact 5	1.33 kilohms	L22-14,R22-38 R22-39	
V22-12,contact 5	G22-37	3 "	R22-40	
V22-16,contact 3	V22-16,contact 4	100 ohms	R22-44	
V22-16,contact 3	V22-16,contact 5	500 kilohms	R22-45,R22-46	
V22-18,contact 8	V22-16,contact 5	22 "	R22-46	
V22-18,contact 3,5	V22-18,contact 6	10 "	R22-48	
V22-18,contact 6	Zw22-5,contact 1	4.7 "	R22-47	
V22-18,contact 4	Zw22-5,contact 1	4.7-94 "	R22-50,R22-49	With R22-50 in extreme positions
V22-19,contact 4,6	Zw22-5,contact 1	295 "	R22-49,R22-50 R22-51,R22-52 R22-53,R22-55 R22-56	
V22-21,contact 2	Zw22-5,contact 1	265 "	R22-49,R22-50 R22-51,R22-55 R22-56	
V22-20,contact 5	Zw22-5,contact 1	170 "	R22-50,R22-49 R22-51,R22-21 R22-50,R22-49 R22-55,R22-56 R22-59,R22-22	
V22-22,cap	V22-7,contact 8	900 "	R22-60	W22-4 set at AFC
Zw22-5,contact 9	Zw22-5,contact 1	Not less than 50 megohms	Insulation resistance	
Zw22-5,contact 10	Zw22-5,contact 1	"	"	

Driver unit

V23-1,contact 3,6	Zw23-1,contact 8	0		
V23-1,contact 4	Zw23-1,contact 8	7.5 kilohms	R23-2	
V23-1,contact 5	V23-1,contact 2	15 "	R23-5,R23-6,L23-1	
V23-2,contact 3	DL23-2,contact 1	8 "	L23-2,R23-10 DL23-2	
V23-2,contact 5	Zw23-1,contact 8	47 "	R23-9	
V23-3,contact 4	Zw23-1,contact 8	0		
V23-3,contact 2,6	V23-4,contact 2,6	80 "	R23-13,R23-14 R23-11,R23-12 Tr23-1,R23-18 R23-19	
V23-4,contact 4	Zw23-1,contact 8	0		
V23-4,contact A_1 and A_2	Zw23-2	5.1 "	R23-28,R23-20 R23-26	
V25-3,contact A_1 and A_2	Zw23-2	5.1 "	R23-28,R23-21 R23-27	
Zw23-1,contact 11	Zw23-1,contact 8	Not less than 10 megohms	Insulation resistance	

Zw23-1,contact 15	Zw23-1,contact 8	Not less than 10 megohms	Insulation resistance	
Zw23-1,contact 13	Zw23-1,contact 8	Not less than 50 megohms	"	
Zw23-2	Zw23-1,contact 8	Not less than 100 megohms	"	
Zw23-6	Zw23-1,contact 8	"	"	
Zw23-7	Zw23-1,contact 8	"	"	

Modulator-oscillator unit

P125-1,contact 3	P125-2,contact 4	Not less than 3 megohms	Insulation resistance	Close contacts P25-1,P25-2 and W25-1
P125-1,contact 4	P125-2,contact 4	"	"	"
P125-2,contact 1	P125-2,contact 4	"	"	"
P125-2,contact 2	P125-2,contact 4	"	"	"
P125-2,contact 3	P125-2,contact 4	"	"	"

Drive motor excitation rectifier unit

P166-1,contact 4	P166-1,contact 5	1.3 ohms	Tr66-1
V66-1,contact 4	P166-1,contact 6	55 "	Tr66-1
P166-1,contact 3	P166-1,contact 1	31 kilohms	R66-1,R66-2,R66-3
P166-1,contact 4 or 5	P166-1,contact 1	Not less than 50 megohms	Insulation resistance

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Voltage Chart

Measurement between points		Voltage value V	Notes
Automatic tracking channel amplifier unit			
V1-1, contact 4	Zw1-6, contact 4	0-(-13)	With R1-44 in extreme positions
V1-1, contact 5	Zw1-6, contact 4	0-(1.5)	" "
V1-1, contact 6	Zw1-6, contact 4	115	
V1-1, contact 8	Zw1-6, contact 4	110	
V1-2, contact 5	Zw1-6, contact 4	1.3	
V1-2, contact 6	Zw1-6, contact 4	115	
V1-2, contact 8	Zw1-6, contact 4	110	
V1-3, contact 5	Zw1-6, contact 4	1.3	
V1-3, contact 6	Zw1-6, contact 4	115	
V1-3, contact 8	Zw1-6, contact 4	112	
V1-4, contact 5	Zw1-6, contact 4	1.3	
V1-4, contact 6	Zw1-6, contact 4	115	
V1-4, contact 8	Zw1-6, contact 4	112	
V1-5, contact 5	Zw1-6, contact 4	1-5.5	With R1-21 in extreme positions
V1-5, contact 6	Zw1-6, contact 4	- 9.5	W1-3 set at GATE
V1-5, contact 8	Zw1-6, contact 4	300	W1-3 set at -120V
V1-6, contact 5	Zw1-6, contact 4	1.65	
V1-6, contact 6	Zw1-6, contact 4	145	
V1-6, contact 8	Zw1-6, contact 4	280	
V1-8, contact 5	Zw1-6, contact 4	5.8	
V1-8, contact 6,8	Zw1-6, contact 4	260	
V1-9, contact 5	Zw1-6, contact 4	14	
V1-9, contact 6	Zw1-6, contact 4	300	
V1-9, contact 8	Zw1-6, contact 4	300	
V1-10, contact 4	Zw1-6, contact 4	-(1.5-17)	With R1-44 in extreme positions
V1-10, contact 5	Zw1-6, contact 4	120	With R1-54 in extreme positions
V1-10, contact 6	Zw1-6, contact 4	0	Set by R1-42, with R1-44 turned fully clockwise
V1-10, contact 7	Zw1-6, contact 4	6.3 A.C.	
V1-11, contact 2	V1-11, contact 7	6.3 A.C.	
V1-11, contact 6	Zw1-6, contact 4	120	
V1-11, contact 8	Zw1-6, contact 4	107	
V1-11, contact 5	Zw1-6, contact 4	1.3	

Note: With R1-44 in extreme right position and contacts 3 and 5 of Zw1-6 shorted.

Measurement between points		Voltage value V	Notes
Range channel amplifier unit			
V2-1, contact 5	Zw2-4, contact 3,4	0.7-9.5	With R2-3 in extreme positions
V2-1, contact 6	Zw2-4, contact 3,4	110-280	" " "
V2-1, contact 8	Zw2-4, contact 3,4	260-300	
V2-3, contact 4	Zw2-4, contact 3,4	- 1	
V2-3, contact 8	Zw2-4, contact 3,4	180	
V2-4, contact 5	Zw2-4, contact 3,4	2.2	
V2-4, contact 8	Zw2-4, contact 3,4	95	
V2-5, contact 3	Zw2-4, contact 3,4	230	
V2-5, contact 4	Zw2-4, contact 3,4	280	
V2-5, contact 5	Zw2-4, contact 3,4	-19	
V2-5, contact 8	Zw2-4, contact 3,4	2.5	
V2-1, contact 7	V2-1, contact 2	6.3 A.C.	
V2-10, contact 2	Zw2-4, contact 3,4	-105	

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Range indicator unit (main voltages)

V3-1, contact 7	W3-1, contact 8	6.3 A.C.	
V3-2, contact 2	V3-2, contact 7	6.3 A.C.	
V3-3, contact 7	V3-4, contact 8	6.3 A.C.	
V3-4, contact 7	V3-5, contact 8	6.3 A.C.	
V3-5, contact 7	V3-5, contact 8	6.3 A.C.	
Zw3-1, contact 5	Zw3-1, contact 9	270	
Pl3-1, contact 1	Zw3-1, contact 9	490	

Range mechanism unit (main voltages)

V4-1, contact 7	V4-1, contact 8	6.3 A.C.	
V4-2, contact 2	V4-2, contact 7	6.3 A.C.	
Zw4-3, contact 6	Zw4-3, contact 10	270	
G4-1	Zw4-3, contact 10	0.85 A.C.	Measured by WLU-2
G4-6	Zw4-3, contact 10	Not less than 3 A.C.	Measured by WLU-2

Power pack of range measuring and plan position indicator systems

Tr5-1, contact 1	Tr5-1, contact 2	110 A.C.	
Tr5-2, contact 1	Tr5-2, contact 2	110 A.C.	
Tr5-3, contact 1	Tr5-3, contact 2	110 A.C.	
V5-2, contact 2	V5-2, contact 8	5 A.C.	
V5-3, contact 2	V5-3, contact 8	5 A.C.	
V5-11, contact 2	V5-11, contact 8	5 A.C.	
V5-1, contact 2	V5-1, contact 7	2.5 A.C.	
V5-8, contact 2	V5-8, contact 7	6.3 A.C.	
V5-4, contact 4	V5-4, contact 8	12.6 A.C.	
V5-5, contact 4	V5-5, contact 8	12.6 A.C.	
V5-6, contact 4	V5-6, contact 8	12.6 A.C.	
V5-7, contact 4	V5-7, contact 8	12.6 A.C.	
V5-4, contact 6	Tr5-2, contact 4	490	
V5-4, contact 1	Tr5-2, contact 4	270	Set by R5-23
G5-3, contact 2	G5-3, contact 4	-1700	
Zw5-4	Tr5-2, contact 4	4800	

Automatic tracking unit

Tr6-1, contact 1	Tr6-1, contact 2	110 A.C.	
G6-1	G6-5	75	
G6-2	G6-5	0	
G6-3	G6-5	0	
G6-4	G6-5	3	Set by R6-12
G6-5	Chassis	0	
G6-6	G6-5	75	
G6-7	G6-5	75	
V6-1, contact 2 or 8	G6-5	320	
V6-1, contact 4 or 6	G6-5	405 A.C.	
V6-1, contact 2	V6-1, contact 8	5 A.C.	
V6-2, contact 2	V6-2, contact 7	6.5 A.C.	
V6-2, contact 3 or 5	G6-5	-1	R6-6 set fully clockwise
V6-2, contact 4 or 8	G6-5	0	
V6-3, contact 2	V6-3, contact 7	6.5 A.C.	
V6-3, contact 8	G6-5	113	R6-6 set fully counter-clockwise
V6-3, contact 6	G6-5	105	
V6-4, contact 3 or 5	G6-5	0	

V6-4, contact 7	V6-4, contact 8	6.6 A.C.	
V6-4, contact 1 or 4	G6-5	0	
V6-4, contact 3 or 6	G6-5	3	Set by R6-12
V6-4, contact 2 or 5	G6-5	105	
V6-5, contact 2	G6-5	0	
V6-5, contact 5	G6-5	105	
Tr6-1, contact 8	Tr6-1, contact 10	6.5 A.C.	
G6-2, contact 2	G6-5	300	
Tr6-3, contact 1	Tr6-3, contact 2	110 A.C.	
Tr6-3, contact 3	Tr6-2, contact 4	5.5 A.C.	

Automatic range finder unit (main voltages)

V7-1, contact 2	V7-1, contact 7	6.3 A.C.	
V7-2, contact 2	V7-2, contact 7	6.3 A.C.	
V7-3, contact 2	V7-3, contact 7	6.3 A.C.	
V7-4, contact 2	V7-4, contact 7	6.3 A.C.	
V7-5, contact 2	V7-5, contact 7	6.3 A.C.	
V7-6, contact 2	V7-6, contact 7	6.3 A.C.	
V7-7, contact 2	V7-7, contact 7	6.3 A.C.	
V7-8, contact 7	V7-8, contact 8	6.3 A.C.	
V7-9, contact 2	V7-9, contact 7	6.3 A.C.	
V7-10, contact 2	V7-10, contact 7	6.3 A.C.	
V7-11, contact 7	V7-11, contact 8	6.3 A.C.	
V7-13, contact 2	V7-13, contact 7	6.3 A.C.	
V7-14, contact 7	V7-14, contact 8	6.3 A.C.	
V7-15, contact 7	V7-15, contact 8	6.3 A.C.	
V7-16, contact 7	V7-16, contact 8	6.3 A.C.	
V7-17, contact 2	V7-17, contact 7	6.8 A.C.	
G7-5	Zw7-1, contact 9,10 or chassis	270	
G7-2	Zw7-1, contact 9,10 or chassis	500	
G7-11	Zw7-1, contact 9,10 or chassis	90-120	With R7-80 in extreme positions

Range unit (main voltages)

V8-1, contact 2	V8-1, contact 7	6.3 A.C.	
V8-2, contact 7	V8-2, contact 8	6.3 A.C.	
V8-3, contact 7	V8-3, contact 8	6.3 A.C.	
V8-4, contact 7	V8-4, contact 8	6.3 A.C.	
V8-5, contact 2	V8-5, contact 7	6.3 A.C.	
V8-6, contact 7	V8-6, contact 8	6.3 A.C.	
V8-7, contact 7	V8-7, contact 8	6.3 A.C.	
V8-8, contact 7	V8-8, contact 8	6.3 A.C.	
V8-9, contact 2	V8-9, contact 7	6.3 A.C.	
V8-10, contact 2	V8-10, contact 7	6.3 A.C.	
V8-11, contact 2	V8-11, contact 7	6.3 A.C.	
V8-12, contact 2	V8-12, contact 7	6.3 A.C.	
V8-13, contact 2	V8-13, contact 7	6.3 A.C.	
V8-14, contact 7	V8-14, contact 8	6.3 A.C.	
V8-15, contact 7	V8-15, contact 8	6.8 A.C.	
V8-16, contact 7	V8-16, contact 8	6.3 A.C.	
V8-17, contact 2	V8-17, contact 7	6.3 A.C.	
G8-14	Zw8-2, contact 1,2 or chassis	270	

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Power pack of range measuring system

Tr9-1,contact 1	Tr9-1,contact 2	110 A.C.
Tr9-2,contact 1	Tr9-2,contact 2	110 A.C.
V9-1,contact 2	V9-1,contact 8	5 A.C.
V9-2,contact 2	V9-2,contact 8	5 A.C.
V9-5,contact 2	V9-5,contact 8	5 A.C.
G9-2,contact 1	G9-2,contact 2	500
V9-4,contact 2	V9-3,contact 5	-210

Azimuth and elevation tracking unit

G10-1	G10-3	76
G10-2	G10-3	76
G10-3	Chassis	0
G10-4	G10-3	76
G10-5	G10-3	76
G10-6	G10-3	240
G10-7	G10-3	240
G10-11	G10-3	38
G10-12	G10-3	22
G10-13	G10-3	36
G10-14	G10-3	34
G10-51	G10-3	76
G10-52	G10-3	76
G10-53	G10-3	0
G10-54	G10-3	76
G10-55	G10-3	76
G10-56	G10-3	225
G10-57	G10-3	225
V10-1,contact 1	G10-3	70
V10-1,contact 4	G10-3	70
V10-1,contact 2	G10-3	125
V10-1,contact 5	G10-3	125
V10-2,contact 1	G10-3	70
V10-2,contact 4	G10-3	70
V10-2,contact 2	G10-3	125
V10-2,contact 5	G10-3	125
V10-3,contact 3 and 6	G10-3	0
V10-3,contact 1	G10-3	-42
V10-3,contact 4	G10-3	-42
V10-3,contact 2	G10-3	125
V10-3,contact 5	G10-3	125
V10-51,contact 1	G10-3	70
V10-51,contact 4	G10-3	70
V10-51,contact 2	G10-3	125
V10-51,contact 5	G10-3	125
V10-52,contact 1	G10-3	70
V10-52,contact 4	G10-3	70
V10-52,contact 2	G10-3	125
V10-52,contact 5	G10-3	125
V10-53,contact 3,6	G10-3	0
V10-53,contact 1	G10-3	-42
V10-53,contact 4	G10-3	-42
V10-53,contact 2	G10-3	125
V10-53,contact 5	G10-3	125
V10-4,contact 8	G10-3	90
V10-4,contact 4	G10-3	225
V10-4,contact 3	G10-3	240
V10-5,contact 8	G10-3	90
V10-5,contact 4	G10-3	225
V10-5,contact 3	G10-3	240
V10-54,contact 8	G10-3	90

V10-54, contact 4	G10-3	225	
V10-54, contact 3	G10-3	225	
V10-55, contact 8	G10-3	90	
V10-55, contact 4	G10-3	225	
V10-55, contact 3	G10-3	225	
V10-6, contact 3,6	G10-3	38	
V10-6, contact 1	G10-3	30	
V10-6, contact 4	G10-3	30	
V10-6, contact 2	G10-3	225	
V10-6, contact 5	G10-3	225	
V10-7, contact 3,6	G10-3	38	
V10-7, contact 1	G10-3	30	
V10-7, contact 4	G10-3	30	
V10-7, contact 2	G10-3	225	
V10-7, contact 5	G10-3	225	
V10-56, contact 3,6	G10-3	38	
V10-56, contact 1	G10-3	30	
V10-56, contact 4	G10-3	30	
V10-56, contact 2	G10-3	225	
V10-56, contact 5	G10-3	225	
V10-57, contact 3,6	G10-3	38	
V10-57, contact 1	G10-3	30	
V10-57, contact 4	G10-3	30	
V10-57, contact 2	G10-3	225	
V10-57, contact 5	G10-3	225	
V10-8, contact 4	G10-3	30	
V10-8, contact 8	G10-3	38	
V10-8, contact 3	G10-3	22	
V10-8, contact 5	G10-3	30	
V10-58, contact 4	G10-3	30	
V10-58, contact 8	G10-3	38	
V10-58, contact 3	G10-3	22	
G10-58, contact 5	G10-3	30	
V10-9, contact 3,6	G10-3	34	
V10-9, contact 1	G10-3	30	
V10-9, contact 4	G10-3	30	
V10-59, contact 3,6	G10-3	34	
V10-59, contact 1	G10-3	30	
V10-59, contact 4	G10-3	30	

Plan position indicator unit (main voltages)

V11-1, contact 7	V11-1, contact 8	6.3 A.C.	
V11-2, contact 7	V11-2, contact 8	6.3 A.C.	
V11-3, contact 7	V11-3, contact 8	6.3 A.C.	
V11-4, contact 2	V11-4, contact 7	6.3 A.C.	
V11-5, contact 7	V11-5, contact 8	6.3 A.C.	
V11-6, contact 7	V11-6, contact 8	6.3 A.C.	
V11-7, contact 7	V11-7, contact 8	6.3 A.C.	
V11-8, contact 7	V11-8, contact 8	6.3 A.C.	
V11-9, contact 2	V11-9, contact 8	6.3 A.C.	Measured with the socket removed
V11-11, contact 2	V11-11, contact 7	6.3 A.C.	
V11-12, contact 2	V11-12, contact 7	6.3 A.C.	
Zw11-1, contact 5	Zw11-2, contact 2	270	
Zw11-2, contact 6	Zw11-2, contact 2	270	

Antenna control unit

Zw12-2, contact 9	Zw12-2, contact 10	110 A.C.	
Zw12-2, contact 1	Tr12-2, contact 2	110 A.C.	
M12-3, contact 2	M12-3, contact 4	20 A.C.	
Tr12-52, contact 1	Tr12-52, contact 2	110 A.C.	
M12-52, contact 2	M12-52, contact 4	20 A.C.	

Zw12-1, contact 11	Zw12-1, contact 12	0-55 A.C.	Amplidyne is off when
Zw12-1, contact 11	Zw12-1, contact 9	0-55 A.C.	azimuth hand-wheel is
Zw12-1, contact 9	Zw12-1, contact 12	0-55 A.C.	rotated
Zw12-1, contact 2	Zw12-2, contact 6	0-55 A.C.	Amplidyne is off when
Zw12-1, contact 2	Zw12-2, contact 8	0-55 A.C.	elevation hand-wheel
Zw12-2, contact 6	Zw12-2, contact 8	0-55 A.C.	is rotated
M12-2, contact 2	M12-2, contact 4	110 A.C.	W12-1 set at SCAN

Control panel

Pl13-1, contact 2	Pl13-1, contact 3,4	220 A.C.	
Pl13-1, contact 3	Pl13-1, contact 4	220 A.C.	
Pl13-2, contact 1	Pl13-2, contact 2,12	220 A.C.	Switch on reference voltage generator
Pl13-2, contact 2	Pl13-2, contact 12	220 A.C.	" " "
Pl13-2, contact 4	Pl13-2, contact 5	220 A.C.	Switch on elevation amplidyne
Pl13-2, contact 3	Pl13-2, contact 4,5	220 A.C.	" " "
Pl13-2, contact 6	Pl13-2, contact 7,8	220 A.C.	Switch on azimuth amplidyne
Pl13-2, contact 7	Pl13-2, contact 8	220 A.C.	" " "
Pl13-2, contact 9	Pl13-2, contact 10,11	220 A.C.	Switch on dehydrator
Pl13-2, contact 10	Pl13-2, contact 11	220 A.C.	" " "
Pl13-3, contact 1, 3,5	Pl13-3, contact 2,4,6	110 A.C.	Switch on W13-4
Pl13-3, contact 9	Pl13-3, contact 10	110 A.C.	Switch on W13-3
Pl13-4, contact 3	Pl13-4, contact 4,9	33 A.C.	Switch on reference voltage generator
Pl13-4, contact 6	Pl13-4, contact 5,7, 8,10	100 A.C.	" " "
Pl13-5, contact 1, 2,3,4,9	Pl13-6, contact 1,2, 3,4,9	110 A.C.	
Pl13-5, contact 10	Pl13-5, contact 11	110 A.C.	
Pl13-6, contact 11	Pl13-6, contact 12	220 A.C.	Switch on main control board heaters
Pl13-7, contact 2	Pl13-7, contact 3	110 A.C.	

I-F preamplifier unit

V22-1, contact 5	Zw22-5, contact 1	1.4-6	With R22-63 in
V22-1, contact 6	Zw22-5, contact 1	160	extreme positions
V22-1, contact 8	Zw22-5, contact 1	160	R22-63 set fully
V22-2, contact 5	Zw22-5, contact 1	2.0	counter-clockwise
V22-2, contact 6	Zw22-5, contact 1	160	
V22-2, contact 8	Zw22-5, contact 1	160	
V22-3, contact 5	Zw22-5, contact 1	2.0	
V22-3, contact 6	Zw22-5, contact 1	160	
V22-3, contact 8	Zw22-5, contact 1	160	
V22-5, contact 8	Zw22-5, contact 1	250	
V22-6, contact 4	Zw22-5, contact 1	-505	
V22-7, contact 5	Zw22-5, contact 1	-505	
V22-8, contact 2	Zw22-5, contact 1	2.0	
V22-8, contact 5	Zw22-5, contact 1	125	
V22-9, contact 2	Zw22-5, contact 1	2.0	
V22-9, contact 5	Zw22-5, contact 1	125	
V22-10, contact 5	Zw22-5, contact 1	1.9	
V22-10, contact 6	Zw22-5, contact 1	145	
V22-10, contact 8	Zw22-5, contact 1	140	
V22-16, contact 3	Zw22-5, contact 1	375	
V22-16, contact 4	Zw22-5, contact 1	375	
V22-18, contact 3	Zw22-5, contact 1	-107	At -250 V across G22-2
V22-18, contact 6	Zw22-5, contact 1	-32	" " " "
V22-18, contact 4	Zw22-5, contact 1	-110	" " " "
V22-18, contact 8	Zw22-5, contact 1	-36	" " " "

Tr22-5,contact 5	Tr22-5,contact 10	6.3 A.C.	
V22-18,contact 2	V22-18,contact 7	6.3 A.C.	
V22-16,contact 2	V22-16, contact 7	6.3 A.C.	
V22-8,contact 3	V22-8,contact 4	6.3 A.C.	
V22-1,contact 2	V22-1,contact 7	6.3 A.C.	
V22-6,contact 2	V22-6,contact 7	6.3 A.C.	

Driver unit

V23-1,contact 3,6	Zw23-1,contact 8	0	
V23-2,contact 8	Zw23-1,contact 8	0	
V23-3,contact 4	Zw23-1,contact 8	0	
V23-4,contact 4	Zw23-1,contact 8	0	
V23-5,contact 4	Zw23-1,contact 8	0	
V23-1,contact 7	Zw23-1,contact 8	6.3 A.C.	
V23-2,contact 7	Zw23-1,contact 8	6.3 A.C.	
V23-3,contact 1,7	Zw23-1,contact 8	6.3 A.C.	
V23-4,contact 1,7	Zw23-1,contact 8	6.3 A.C.	
V23-5,contact 1,7	Zw23-1,contact 8	6.3 A.C.	
V23-6,contact 2	V23-6,contact 8	5 A.C.	
V23-7,contact 2	V23-7,contact 8	5 A.C.	
V23-8,contact 2	V23-8,contact 8	5 A.C.	
V23-1,contact 1	Zw23-1,contact 8	-17	Measured by valve voltmeter WX-2 or the like
V23-3,contact 2,6	Zw23-1,contact 8	-232(-223)	" " " " "
V23-4,contact 2,6	Zw23-1,contact 8	-232(-223)	" " " " "
V23-5,contact 2,6	Zw23-1,contact 8	-232(-223)	" " " " "
V23-1,contact 5	Zw23-1,contact 8	115(105)	" " " " "
V23-1,contact 2	Zw23-1,contact 8	235(220)	" " " " "
V23-2,contact 3,4	Zw23-1,contact 8	105(102)	" " " " "
V23-3,contact 3	Zw23-1,contact 8	910(840)	" " " " "
V23-4,contact 3	Zw23-1,contact 8	910(840)	" " " " "
V23-5,contact 3	Zw23-1,contact 8	910(840)	" " " " "
V23-3,contact A_1	Zw23-1,contact 8	910(840)	" " " " "
V23-3,contact A_2	Zw23-1,contact 8	910(840)	" " " " "

Notes: 1. Given in brackets are approximate voltage values corresponding to measurements taken by a meter, type AVO-5M. The difference in measurements is caused by different input resistances of the devices.
2. Take measurements with the range measuring system de-energized.

Modulator-oscillator unit

Tr25-10,contact 3	Tr25-10,contact 4	4 A.C.	
Tr25-5,contact 3	Tr25-5,contact 4	4 A.C.	
P125-11	P125-12	5.3 A.C.	
P125-9	P125-10	8.2 A.C.	
Tr25-3,contact 5	Tr25-3,contact 4	6.3 A.C.	
Tr25-8,contact 9	Tr25-8,contact 10	5 A.C.	
Tr25-8,contact 11	Tr25-8,contact 12	5 A.C.	
V25-1, grid	Chassis	-1350(-1275)	Measured by electrostatic voltmeter
V25-2, grid	Chassis	-1350(1275)	" " " "
V25-3, grid	Chassis	-1350(1275)	" " " "
Zw25-8	Chassis	-820(-735)	" " " "
Tr25-5,contact 4	Chassis	3900(3950)	" " " "

Notes: 1. Given in brackets are approximate voltage values corresponding to measurements taken by a meter, type AVO-5M. The difference in measurements is caused by different input resistances of the devices.
2. Take measurements with the range measuring system de-energized.

Antenna pedestal

P132-1, contact 2,1	P132-1, contact 3	0-50 A.C.	
P132-1, contact 1	P132-1, contact 2	0-50 A.C.	
P132-1, contact 4	P132-1, contact 5	110 A.C.	
P132-1, contact 6	P132-1, contact 7,1	0-50 A.C.	
P132-1, contact 7	P132-1, contact 1	0-50 A.C.	
P132-2, contact 12	P132-1, contact 11	26 A.C.	Function switch on antenna control unit is set at AUTOMATIC
P132-2, contact 2	P132-2, contact 8	0-100	Depends upon azimuth speed of pedestal
P132-2, contact 4	P132-2, contact 5	300	
P132-2, contact 6	P132-5, contact 10	0-100	Depends upon elevation speed of pedestal
P132-2, contact 9	P132-2, contact 11	0-220	Depends upon rotor speed of M32-56
P132-2, contact 10	P132-2, contact 1	0-220	Depends upon rotor speed of M32-6
P132-3, contact 1	P132-3, contact 2,8	0-50 A.C.	
P132-3, contact 2	P132-3, contact 8	0-50 A.C.	
P132-3, contact 3	P132-3, contact 4	0-50 A.C.	When turning azimuth handwheel. Switch off amplidyne
P132-3, contact 5	P132-3, contact 6,7	0-50 A.C.	" " " " " "
P132-3, contact 6	P132-3, contact 7	0-50 A.C.	" " " " " "
P132-3, contact 10	P132-4, contact 5	0-50 A.C.	When turning elevation hand-wheel. Switch off elevation amplidyne
P132-4, contact 3	P132-4, contact 4	0-50 A.C.	" " " " " "
P132-4, contact 6	P132-4, contact 7,8	220 A.C.	Reference voltage generator energized
P132-4, contact 7	P132-4, contact 8	220 A.C.	" " " " "
P132-4, contact 12	P132-5, contact 12	0-50 A.C.	When turning elevation hand-wheel. Switch off elevation amplidyne
P132-5, contact 2	P132-5, contact 1,3	33 A.C.	
P132-5, contact 5	P132-5, contact 10	0-100	Depends upon elevation speed
P132-5, contact 6	P132-5, contact 7,8	0-50 A.C.	When turning elevation hand-wheel. Switch off elevation amplidyne
P132-5, contact 7	P132-5, contact 8	0-50 A.C.	When turning elevation hand-wheel. Switch off elevation amplidyne
P132-5, contact 9	P132-5, contact 10	0-100	Depends upon elevation speed of pedestal

Drive motor excitation rectifier

P166-1, contact 3	P166-1, contact 1	300	
Tr66-1, contact 1	Tr66-1, contact 2	110 A.C.	
V66-1, contact 6	P166-1, contact 1	390 A.C.	
V66-1, contact 4	P166-1, contact 1	390 A.C.	

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VOLTAGES ACROSS CONNECTORS OF MAIN CONTROL BOARD WITH UNIT REMOVED

Automatic tracking channel amplifier unit

Zw1-6, contact 1	Zw1-6, contact 2	110 A.C.	Function switch on antenna control unit is set at AUTOMATIC
Zw1-6, contact 6	Zw1-6, contact 4	-105	
Zw1-6, contact 8	Zw1-6, contact 4	300	
Zw1-6, contact 9	Zw1-6, contact 10	110 A.C.	

Range channel amplifier unit

Zw2-4, contact 9	Zw2-4, contact 10	110 A.C.	

Range indicator unit

Zw3-1, contact 1	Zw3-1, contact 2	6.3 A.C.	
Zw3-1, contact 3	Zw3-1, contact 9	-(15-100)	Depends upon position of R5-18 (power pack of range measuring and plan position indicator systems)
Zw3-1, contact 4	Zw3-1, contact 9	-28	
Zw3-1, contact 5	Zw3-1, contact 9	270	
Zw3-1, contact 7	Zw3-1, contact 9	490	
Zw3-3	Zw3-1, contact 9	-1700	

Range mechanism unit

Zw4-3, contact 2	Zw4-3, contact 4	6.3 A.C.	
Zw4-3, contact 6	Zw4-3, contact 10	270	
Zw4-3, contact 11	Zw4-3, contact 13	110 A.C.	
Zw4-4, contact 7	Zw4-4, contact 9	220 A.C.	With high voltage off in modulator-oscillator unit
Zw4-4, contact 14	Zw4-4, contact 16	110 A.C.	
Zw4-4, contact 10	Zw4-4, contact 12	110 A.C.	

Power pack of range measuring and plan position indicator systems

Zw5-2, contact 13	Zw5-2, contact 16	110 A.C.	
Zw5-3, contact 9,10	Zw5-3, contact 11,12	110 A.C.	

Automatic tracking unit

Zw6-1, contact 6	Zw6-1, contact 7	110 A.C.	Press the error signal button on range mechanisms unit
Zw6-1, contact 15	Zw6-1, contact 16	110 A.C.	
Zw6-2, contact 2	Zw6-2, contact 4	(0-50) A.C	
Zw6-2, contact 4	Zw6-2, contact 15	(0-50) A.C	
Zw6-2, contact 12	Zw6-2, contact 13	(0-50) A.C	
Zw6-2, contact 13	Zw6-2, contact 15	(0-50) A.C	
Zw6-2, contact 6	Zw6-2, contact 10	110 A.C.	

Automatic range finder unit

Zw7-1, contact 1	Zw7-1, contact 2	6.3 A.C.	
Zw7-1, contact 5	Zw7-1, contact 9	500	
Zw7-1, contact 6	Zw7-1, contact 9	270	
Zw7-2, contact 3	Zw7-2, contact 4	110 A.C.	

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Range unit

Zw8-1, contact 1	Zw8-1, contact 2	6.3 A.C.	
Zw8-1, contact 5	Zw8-1, contact 10	-5	Voltage may deviate up to ±50%
Zw8-1, contact 6	Zw8-1, contact 10	270	
Zw8-1, contact 7	Zw8-1, contact 10	-210	
Zw8-1, contact 9	Zw8-1, contact 10	-34	Voltage may deviate up to ±50%

Power pack of range measuring system

Zw9-1, contact 1	Zw9-1, contact 2	110 A.C.	
Zw9-1, contact 12	Zw9-1, contact 13	110 A.C.	
Zw9-2, contact 4	Zw9-2, contact 3	270	
Zw9-2, contact 7	Zw9-2, contact 8	110 A.C.	

Azimuth and elevation tracking unit

Zw10-1, contact 2	Zw10-1, contact 4	6.3 A.C.	
Zw10-1, contact 6	Zw10-1, contact 22	[illegible]	
Zw10-1, contact 7	Zw10-1, contact 1	"	
Zw10-1, contact 8	Zw10-1, contact 1	"	
Zw10-1, contact 9	Zw10-1, contact 10	"	Function switch on antenna control unit set at AUTOMATIC
Zw10-1, contact 1	Zw10-1, contact 11	100 A.C.	
Zw10-1, contact 1	Zw10-1, contact 12	100 A.C.	
Zw10-1, contact 15	Zw10-1, contact 17	0-50 A.C.	
Zw10-1, contact 16	Zw10-1, contact 18	0-50 A.C.	
Zw10-2, contact 9	Zw10-2, contact 11, 12, 13, 14	100 A.C.	

Plan position indicator unit

Zw11-1, contact 4	Zw11-1, contact 1	19	
Zw11-1, contact 5	Zw11-1, contact 1	270	
Zw11-1, contact 6	Zw11-1, contact 1	-160	Voltage of up to -400 V (without load) is permissible
Zw11-1, contact 7	Zw11-1, contact 1	490	
Zw11-1, contact 10	Zw11-1, contact 1	-34	
Zw11-2, contact 1	Zw11-2, contact 3	20 A.C.	Voltage of up to 35 V A.C. (without load) is permissible
Zw11-2, contact 7	Zw11-2, contact 9,10	0-50 A.C.	
Zw11-2, contact 9	Zw11-2, contact 10	0-50 A.C.	
Zw11-2, contact 11,12	Zw11-2, contact 13,14	6.3 A.C.	
Zw11-2, contact 15	Zw11-2, contact 16	6.3 A.C.	
Zw11-4	Zw11-1, contact 1	4800	

Antenna control unit

Zw12-1, contact 8	Zw12-1, contact 1	300	
Zw12-1, contact 10	Zw12-2, contact 10	110 A.C.	
Zw12-2, contact 9	Zw12-2, contact 10	110 A.C.	

Notes: 1.- The A.C. voltage, when being measured, is allowed to deviate from the value specified in the chart by ±10%.

2. The valve filament voltage (6.3 V A.C.), when being measured, is allowed to deviate from the value specified in the chart by about ±20% (measured at incomplete load).

3. The D.C. voltage, when being measured, is allowed to deviate from the values specified in the chart by $^{+30}_{-15}$ per cent (measured at incomplete load).

4. Voltages are measured with the radar station and AA fire director energized except for the unit being tested. Disconnect the transmitter high voltage when measuring voltages of the power pack of the range

APPENDICES

Appendix 1

Spare Parts, tools and accessories (ZIP) for the SON-9 station

The spare parts, tools and accessories (ZIP) for the SON-9 are contained in cases inside the station cabin (cases 1, 2, 3, 4, 5, 6 and 7) and inside the truck body (cases 1, 2) and the case with spares for dehydrator AD-220-T. The spare parts, tools and accessories for power unit APG-15 are held in a case and in kits inside the truck body.

Cases 1, 2, 3, 4 and 5 contain:

Case 1 - a magnetron and technical papers for the station;

case 2 - valves 6Z1P, 5C3S, VU-111-D, pilot and dial lighting lamps MN-3, types 14 and 15, a car lamp, crystals DG-S1 and DK-I1, insulator TJF-34, fuses for 1, 2, 3, 5 and 6 and 10 A, coloured caps for pilot lamps, etc;

case 3 - WS and SP type fuses, insulation tape, grinding paper, a soldering bit, tubular solder, an oiler, goggles and tools (round-nose, flat-nose pliers, wire-cutters, screw-drivers, etc);

case 4 - capacitors KSO and KTK, potentiometers, a kilovoltmeter for 30 kV, D.C. milliammeter for 1, 20 and 50 mA, A.C. voltmeters for 150 and 250 V, buttons, fuse holders, limit switches, a dynamometer, selenium and copper-oxide rectifiers, resistor leads, etc.

case 5 - valves 6P3S, GI-30, GU-50, 6P9, 6Z8, 6Z4, 6N8S, 6N9S, 6K3, 6H6S, 5C4S, SG3S, SG4S; discharger ZG-5, klystron K-11, and fuses for 5, 10, 15 and 25 A.

Cases 6 and 7 in the lower part of the transmitter cabinet contain:

case 6 - pilot, testing and telephone cables, a portable lamp, a cable for battery charging and an intermediate cable;

case 7 - a folding chair, hand bellows, a template for mounting the antenna-feeder system, tools and spares for the trailer chassis.

Case 1 contains corrosion-preventive compound, a valve tester and four packing boxes 1-1, 1-2, 1-3 and 2-6;

box 1-1 holds: fitter's tools (a drill, a hack-saw frame, a hand vice, drill chucks, wrenches, screw-drivers, files etc);

box 1-3 holds: valves 7Z1P, 6P9, 6Z8, 6Z4, 6N8S, 6H6S, 6K3, discharger 4378-D, pilot and dial lighting lamps MN-3, types 14 and 15, lamps and the level indicator;

box 2-6 holds: valve GMI-30

packing box 1-2 is empty.

Case 2 contains oscillograph LI-125 and four packing boxes 2-1, 2-2, 2-3 and 2-4;

box 2-1 holds valves GMI-30 and cathode-ray tubes 8LO30 and 18LM35;

box 2-2 holds valves 6P3S, GI-30, GU-50, 2C2S, 5C4S, SG3S, SG4S and ZG-5.

box 2-3 holds valves 5C3S, VU-111-D, W1-0.1/40, W1-0.02/20, magnetrons MI-18-21, klystron K-11, polystyrene cement, a polystyrene housing with an antenna head;

box 2-4 holds capacitors (types KSO, KBG, KTK, KDK, BM, KEG, KPK, RL), resistors (types WS, CP1, PO, PEW), tubular and packet-type switches, tumbler switches, section switches, relays (types ZU, GRW, RM, 10 b), valve sockets, current collector brushes, selsyns connectors, gaskets, fastenings, wires, grade GOJ paste, spares for WEM-5A, drive motor MI-12F and the reference voltage generator.

Case with spares for air dryer AD-220-T is located with the power unit on the truck body.

Components, included in the set of spare parts, tools and accessories for the SON-9, and the number of cases holding these components are fully presented in the list of spare parts, tools and accessories.*

* The list of spare parts, tools and accessories for each station may be altered.

Appendix 2

LIST OF ELECTRONIC VALVES USED IN STATION

Number and type	GOST Fig.& Technical Specification	Quantity	Circuit designation
Radio-frequency pentode 6Z4	01-401-52	22	V1-1, V1-2, V1-3, V1-4, V1-5, V1-6, V1-8, V1-11, V2-1, V2-3, V2-4, V3-2, V4-2, V8-9, V8-10, V8-12, V22-1, V22-2, V22-3, V22-5, V22-7, V22-10
Output pentode 6P9	01-400-52	11	V1-9, V1-14, V5-8, V7-1, V7-2, V7-4, V7-5, V7-6, V7-7, V8-13, V8-17
Transmitting pentode GU-50	11-405-52	5	V1-13, V5-4, V5-5, V5-6, V5-7
Radio-frequency pentode 6Z1P	01-103-52	2	V22-8, V22-9
Radio-frequency pentode 6K3	01-209-53	3	V6-3, V7-13, V8-1
Radio-frequency pentode 6Z8	01-405-52	2	V11-11, V22-18
Beam tetrode 6P3S	01-110-52	12	V2-5, V7-9, V7-10, V8-5, V10-4, V10-5, V10-54, V10-55, V11-4, V11-12, V22-16, V23-2
Double beam tetrode GI-30	11-402-52	3	V23-3, V23-4, V23-5
Double triode 6N8S	01-310-52	36	V1-10, V3-1, V3-3, V3-4, V3-5, V4-1, V6-4, V7-8, V7-11, V7-14, V7-15, V8-6, V8-7, V8-8, V8-14, V8-15, V8-16, V10-1, V10-2, V10-3, V10-6, V10-7, V10-51, V10-52, V10-53, V10-56, V10-57, V11-1, V11-2, V11-3, V11-5, V11-6, V11-7, V11-8, V23-1, V25-23
Double triode 6N9S	01-311-52	6	V7-16, V8-2, V8-3, V8-4, V10-9, V10-59
Pulse triode GMI-30	11-407-52	3	V25-1, V25-2, V25-3
Voltage stabiliser SG3S	02-701-52	8	V1-15, V2-10, V5-9, V6-5, V7-12, V9-3, V9-4, V22-20
Voltage stabiliser SG4S	02-700-52	4	V11-10, V22-12, V22-17, V22-21
Double diode 6H6S	01-220-53	10	V1-7, V2-2, V6-2, V7-3, V7-17, V8-11, V10-8, V10-58, V22-4, V22-6
Kenotron 5G3S	01-418-52	7	V5-2, V5-3, V5-11, V6-1, V9-1, V9-2, V9-5
Kenotron 5G4S	01-227-53	10	V1-12, V2-7, V2-8, V2-9, V22-11, V22-14, V22-19, V23-6, V23-7, V23-8
Kenotron 2G2S	01-508-52	1	V5-1
Kenotron W1-0.02/20	13-401-52	1	V5-10
Kenotron W1-0.1/40	13-400-52	5	V25-4, V25-5, V25-6, V25-11, V25-12
Kenotron VU-111-D	13-102-52	3	V25-8, V25-9, V25-10
Klystron K-11	09-101-52	3	V22-22
Magnotron MI-18-21	06-651-52	1	V25-7
Cathode-ray tube 8L030	07-303-52	2	V3-6, V3-7
Cathode-ray tube 18LM35	07-308-52	1	V11-9
Discharger ZG-5	12-401-52	1	V28-1

Appendix 3

Amplitude-frequency characteristic meter URAL-2 of antenna positioning system of the SON-9 station

1. Follow-up system operation frequency method of analysis

General

At the present time a frequency method of analysis is widely used for the investigation of the follow-up system operation. Basic information on the frequency method given below enables the operating personnel to tune the elements of the follow-up system of the station.

The follow-up system of the station comprises the transmitting, antenna--feeder, receiving and antenna positioning systems. The follow-up system is closed through the space, in which energy in the form of radio waves is emitted by the antenna, and the target, reflecting it as an echo.

The quality of the follow-up system operation is determined by the characteristics of the devices and systems (previously mentioned). Therefore to ensure normal operation of the follow-up system the devices and systems incorporated in it must possess quite definite characteristics.

The main characteristics of the transmitter-receiver which determine the quality of the follow-up system operation are linearity and stability of its nominal parameters (absence of breakdowns in the feeder, normal sensitivity of the receiver, stability of the receiver tuning, stability of heterodyne and magnetron frequencies, etc.).

The space can be considered an inertialess element of the follow-up system, since, due to high propagation velocity of electromagnetic energy, the delay time of signals in it is appreciably shorter than that of the error signals in other elements of the system.

Owing to the automatic gain control acting in the receiver, the attenuation of signals in space can actually be considered constant and independent of the range of the target being tracked.

The input of the follow-up system is furnished with a useful signal dependent on the departure of the target from the antenna electrical axis (error signal) and noise caused by accidental changes of the target reflecting surface. Let us take the case when the tracked target changes its coordinates in azimuth only.

In the absence of noise the input of the antenna positioning system during target tracking is fed with amplitude-modulated voltage pulses:

$$E = E_o \ (1 + m \cos \Omega \ t)$$

where E_o - the amplitude of pulses when the antenna electrical axis is coincident with the target direction;

Ω - modulation frequency amounting to 24 c.p.s. i.e. to the antenna head revolutions per second;

m - modulation depth proportional to the tracking error.

The change of the target coordinate (azimuth) is graphically shown in Fig. 273.

The error of the target tracking of the follow-up system is proportional to its angular rate and therefore the modulation factor is also proportional to the angular rate:

$$m = K\omega_\beta$$

The target azimuth angular rate $\omega\beta$ (Fig.274) can be presented as a sum of components varying sinusoidally (harmonic components), i.e. as a spectrum of the useful signal (Fig.275).

$$\omega_\beta = \sum_{1}^{i=\infty} G\,\omega_{\beta i}$$

For this reason the voltage coming to the input of the antenna positioning system when the target azimuth changes (and there is no noise) is a pulse voltage modulated in amplitude by the frequency spectrum of the useful signal.

In the presence of noise $n(t)$ the pulse voltage will additionally be modulated by noise whose frequency spectrum for a single target is shown in Fig.276.

Thus, during target tracking the voltage pulses modulated by the useful signal and noise arrive at the input of the antenna. The typical envelope of the frequency spectrum of such pulses is shown in Fig.277. The useful signal occupies comparatively narrow band within 24 $\pm$1 c.p.s. The noise occupies a broad band ranging from zero to some dozens of cycles per second.

To track the target with minimum errors, the antenna positioning system must not distort the useful signal and should weaken the noise. For this reason the system must possess appropriate characteristics which can be determined by using various methods. One of the most widely used methods at the present time is a frequency method of analysis of the follow-up system operation.

The essence of this method consists in establishing the required amplitude-frequency and phase-frequency characteristics of the follow-up system on the basis of the input value changes and accuracy in reproduction of this value at the output of the follow-up system.

The amplitude-frequency characteristic of the follow-up system in closed state $Y_o(f)$ is defined as the dependence of the relation of output signal amplitude θ_{output} to amplitude θ_{input} of the input signal varying sinusoidally upon frequency (Fig.278) when the system operates in a closed state, i.e. when the output signal is applied to its input.

The amplitude-frequency characteristic of the follow-up system in an open state $Y(f)$ is defined as the dependence of relation of output signal amplitude θ_{output} to the amplitude of error ε varying sinusoidally upon frequency (Fig.279) when the system operates in an open state.

The phase-frequency characteristic of the follow-up system is defined as the dependence of the phase difference of the output and input signals upon frequency (Fig.280).

The frequency method can be used, provided the follow-up system is linear and the signal arriving at its input can be presented as a sum of harmonic components.

When the input of the follow-up system is furnished with signal:

$$\theta_{input} = \theta_{input\ m} \sin(2\pi ft + \varphi_{input})$$

varying sinusoidally at frequency f, value θ_{output} will vary sinusoidal[ly]

at the same frequency f and its amplitude θ_{output} and phase φ_{output} will be

determined by the amplitude frequency and phase-frequency characteristics of the system:

$$\theta_{output} = Y(f)\theta_{input\ m} \sin(2\pi ft + \varphi_{output})$$

The input signal can be presented as a sum of components varying sinusoidally at frequencies from 0 to ∞, i.e.:

$$\theta_{input}(t) = \sum_{1}^{i=\infty} \theta_{input\ mi} \sin(2\pi f_i + \varphi_{input\ i})$$

Each harmonic component of the input signal of the given frequency will cause the harmonic component at the same frequency at the output of the follow-up system. This component differs from the input signal by amplitude and phase.

The knowledge of the harmonic components at the input of the follow-up system, its amplitude-frequency and phase-frequency makes it possible to find the law governing the variation of the output signal:

$$\theta_{output}(t) = \sum_{1}^{i=\infty} Y_o(f_i)\,\theta_{input\ mi} \sin(2\pi f_i t + \varphi_{output})$$

and the input signal error reproduced by the follow-up system:

$$\varepsilon(t) = \theta_{input}(t) - \theta_{output}(t)$$

Therefore in order to find the value of output signal θ_{output} knowing the value of input signal θ_{input} it is necessary to know how the amplitude and phase of the harmonic component of the input signal change when the latter is passed through the follow-up system. In other words it is necessary to know the frequency characteristics of the follow-up system.

Consider which conditions should be fulfilled by the frequency characteristics so that the follow-up system may exactly reproduce the input signal.

Fig. 281a shows input signal θ_{input} which must be presented by the follow-up system having frequency characteristic $Y_o(f)$ illustrated in Fig.281c. The input signal frequency spectrum $G_{\theta\ input}(f)$ is shown in Fig. 281b.

The value of harmonic component $G_{\theta\ output}(f_i)$ of frequency f_i at the output of the system (Fig.281b) is obtained by multiplying the corresponding harmonic component of input signal $G_{\theta\ input}(f_i)$ (Fig.281b) by amplification factor $Y_o(f_i)$ of the system at the given frequency. The factor is determined by the amplitude frequency characteristic of the follow-up system in a closed state (Fig.281c).

Input signal θ_{input} is exactly repeated by output signal θ_{output} in case the frequency spectrum of the input signal $G_{\theta\ input}(f)$ is exactly repeated by the frequency spectrum of the output signal $G_{\theta\ output}(f)$.

For this purpose all the harmonic components of the input signal frequency spectrum must pass undistorted through the follow-up system. This is feasible when the amplification factor of the follow-up system at all frequencies equals 1 and phase relations between the harmonic components at the output are the same as those at the input. In other words the amplitude--frequency characteristic of the follow-up system must have infinite pass band,

i.e. must be represented by a line (Y'_o (f)in parallel with the frequency axis at a level equal to 1 (Fig.281c).

If the characteristic differs from straight line Y'_o (f) and is curved as $Y_o(f)$ shown in Fig.281c, the output signal (Fig.281c) will reproduce the input signal inexactly.

The follow-up system may have an infinite pass band only in the absence of noise (foreign signals) at the input, since in this case the exact reproduction of the input signal is possible.

In the presence of noise it is necessary to find a compromise between the accuracy of the input signal reproduction and the degree of noise suppression.

For this purpose, the pass band width of the system should be, on the one hand, wide enough to prevent heavy distortions of the useful signal harmonic components, and, on the other hand, narrow enough to bar or weaken noises.

As was mentioned before, the input signal which arrives at the antenna positioning system during the target tracking, consists of two components, namely: useful signal ω_β (t), which is actually an assigned function of time i.e. the law governing the flight of the target being tracked, and noises n (t) caused by the change of the target reflecting surface.

The follow-up system responds to the useful signal with some definite errors springing from the distortion of the useful signal harmonic components and noise reproduction.

The error consists of two components:

$$\varepsilon(t) = \varepsilon_d(t) + \varepsilon_c(t)$$

where $\varepsilon_d(t)$ - the systematic error of the useful signal reproduction caused by the distortion of its harmonic components;

$\varepsilon_c(t)$ - a random error of the useful signal reproduction caused by the noise influence.

Random error $\varepsilon_c(t)$ is determined by the value of mean-square tracking error (ε) equal to

$$\varepsilon = 0.67\sqrt{\bar{\varepsilon}_c^2}$$

where $\sqrt{\bar{\varepsilon}_c^2}$ is the mean-square error (mean arithmetical value of accidental error squares).

The mean-square error is determined by the amplitude-frequency characteristic of the follow-up system in a closed state $Y_o(f)$, by composition of harmonics and noise intensity G_n (f) producing action on the system:

$$\bar{\varepsilon}_c^2 = \int_0^\infty [Y_o(f)]^2 G_n(f)\, df$$

From Fig.268 it is evident that the intensity of noises from a single aircraft at a frequency of 24 c.p.s. (within the pass band of the follow-up system) may be considered constant.

In this case $\bar{\varepsilon}_c^2 = KS$

/where S ...

where S - the area of the amplitude-frequency characteristic in a closed state, whose coordinates are squared (square amplitude-frequency characteristic);

K - the proportionality coefficient.

Thus, in order to find the mean tracking error it is necessary to know the noise level and calculate the area of the amplitude-frequency characteristic of the follow-up system in a closed state.

The fixed error of reproduction of the law governing the motion of the target being tracked $\varepsilon_d(t)$ can be presented as a series of components proportional to the given law of target motion $g(t)$ and its derivatives;

$$\varepsilon_d(t) = C_0 g(t) + C_1 g'(t) + \frac{C_2}{2} g''(t) \ldots .$$

where $C_0 g(t)$ - the static error of the follow-up system;

$C_1 g'(t) = \varepsilon g'(t)$ - the error caused by the angular rate of the target being tracked;

$\frac{C_2}{2} g''(t) = \varepsilon g''(t)$ - the error caused by the acceleration of the target being tracked.

Coefficients C_0, C_1, C_2, etc. are termed error coefficients. They can be determined by the amplitude-frequency characteristic of the follow-up system in an open state.

Coefficient $\frac{1}{C_1}$, equal to the relation of the angular rate of the target being tracked $g'(t)$ and the error occuring at the given rate, is defined as quality factor of the follow-up system.

Thus, to find the fixed tracking error it is necessary to know the law of target motion and its derivatives and determine error coefficient C_0, C_1, C_2, etc. by the amplitude-frequency characteristic of the follow-up system in an open state.

In practice when tuning the follow-up system it is necessary that the tracking errors should be at minimum and not in excess of permissible values.

In this case there is no need for calculating the values of the mean and fixed error as above. Instead it is necessary to proceed from the constants of the amplitude-frequency characteristic of the follow-up system at which the system will track the target with minimum mean and systematic errors not exceeding the permissible values.

To avoid impermissible systematic errors, the quality factor is taken as a constant easily obtainable by experiments. This constant determines the fixed error component caused by the speed of the target being tracked.

In order that the systematic error components, caused by the acceleration and the higher derivatives of the law of target motion do not exceed the permissible values a minimum pass band width of the follow-up system F (fig.282) is set.

If the pass band width is narrower, the harmonic components with higher frequencies caused by the acceleration and the higher derivatives of the law of target motion are passed weakened through the follow-up system. The result is that the systematic tracking error increases.

In order that the mean error of the follow-up system does not exceed

the permissible value, the height of peak A (Fig.282) of the amplitude--frequency characteristic of the system in a closed state is set, (when tuning it) proceeding from the fact that the area of the square amplitude--frequency characteristic with the pass band assigned is proportional, to a certain extent, to its maximum value.

The follow-up system is practically tuned so that:

- the quality factor of the system is at least 100-150 1/sec for the azimuth channel and 50-80 1/sec.for the elevation channel;

- the pass band width for the azimuth channel is within 0.8 and 1.3 c.p.s. (5-8 rd/sec.) and for the elevation channel is within 0.5 and 0.9 c.p.s. (3-6 rd/sec);

- the peak of the amplitude-frequency characteristic of the system in a closed state is not more than 2 (not more than 6 db).

Provided the conditions are fulfilled and the transmitter-receiver operates normally, the radar station will track the target with errors not exceeding the permissible values.

When tuning the sound follow-up system (i.e. when the station coverage is normal, there is no breakdown in the feeder, the magnetron and oscillator frequencies are stable, the components used in the positioning system units are sound and voltages in the units correspond to the normal values), the above parameters of the antenna positioning system are easily obtainable.

In this case the job consists in choosing the position of the gain control knob in the automatic tracking unit and gain control knobs of the feedback circuits in the azimuth and elevation channels of the tracking unit.

The antenna positioning system is actually the system with negative feedback. This means that the signal from the system output is injected into its input in opposition to the input signal. However, since the system is provided with a large quantity of electrical parts (capacitors, inductances, amplidynes, drive motors, antenna capable of moving under its own momentum) making the signal pass slower, negative feedback at some frequencies acts as positive.

If the system gain becomes equal to one at a frequency corresponding to positive feedback, the system will be excited and sustained oscillations will occur in it.

These oscillations can be cancelled by decreasing the system gain, at this frequency (by turning the gain control knob in the automatic tracking unit counter-clockwise.). But this will be simultaneously accompanied by a decrease of gain at the other frequencies including those contained in the spectrum of the useful signal, which will result in an increase of fixed tracking errors.

For this reason the gain of the system should be so selected that its quality factor is not less than the permissible value.

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This in turn depends upon the fact that at low frequencies the feedback voltage phase at the output of the filter (if it contains a choke) varies within 90° and 180° with respect to the voltage taken off the velocity feedback bridge and the feedback becomes positive, not negative.

If the feedback filter does not contain a choke, the feedback voltage

phase varies within 0 and 90° with feedback remaining negative at all frequencies. But in this case the gain of the feedback circuit should not be very high as it will result in the pass band of the system being greatly narrowed and, consequently, fixed tracking errors will increase.

Therefore the feedback magnitude is selected so that the peak of the amplitude-frequency characteristic is minimum and the system pass band is not less than permissible.

The above characteristics of the follow-up system are checked by means of an amplitude-frequency characteristic meter,"URAL-2".

The system, while being tuned, is considered faulty if permissible values for quality factor, pass band and peak of the amplitude-frequency characteristic cannot be obtained.

2. Measuring the Bearing Characteristic of the SON-9 Station

In order to determine the input signal voltage when measuring the amplitude-frequency characteristic of the station it is necessary to determine its bearing characteristic, i.e. dependence of the voltage magnitude at the output of the azimuth and elevation tracking unit upon the mismatch angle between the antenna electrical axis and the target direction.

The bearing characteristic is measured with the use of a reference landmark during automatic range tracking.

The landmark must fulfil the conditions specified in Part 2, Chapter 10, Section 7. The local objects around it should not be nearer than 200 m. in range and 1-00 in angular coordinates. It is necessary that the reference landmark should have small angular sizes in azimuth (not greater than 0-02).

To determine the slope of the bearing characteristic curve proceed as follows:

(a) Aim the antenna directly at the reference landmark, set the function switch MODE of OPERATION at AUTOMATIC.

Use instrument AVO-5 to check balancing of the azimuth and elevation tracking unit (voltage across jacks EXCITATION should be equal to zero when button ERROR SIGNAL OFF on the range mechanism unit is depressed).

(b) Check for evidence of breakdowns in the antenna-feeder system.

(c) Check whether signals are modulated in amplitude and frequency; for this purpose switch off the amplidyne and reference voltage generator. The top of the pulse reflected from the landmark as an echo, which can be seen on the fine range indicator, should not be blurred by more than 30 per cent as compared with the sweep trace thickness.

(d) Attach connector ZW3-7 of the range indicator unit to the input of the automatic tracking unit (jack INPUT) since the landmark echo must arrive at the automatic tracking unit every repetition period. In this case the sweep must not slip in the base of the pulse observed on the fine range indicator.

(e) Use the AGC potentiometer of the automatic tracking unit to set 6.5 mA on instrument PLATE CURRENT.

(f) Set the voltage values across the jacks of the automatic tracking and azimuth and elevation tracking units as instructed in Part II, Chapter 10, Section I, under Subsection "Tuning the System during Manual Antenna Control", Points 2-4 and Section 7 Points 1,2.

(g) Move the antenna off the reference landmark by 0-10 in azimuth and switch off the amplidynes; set knob AMPLIFICATION of the automatic tracking unit at "5" and switch MODE OF OPERATION to AUTOMATIC. Use instrument AVO-5 to measure excitation voltage across jacks EXCITATION in the elevation channel of the azimuth and elevation tracking unit; the excitation voltage for the elevation channel is not to be greater than 5 V. If it is, adjust the reference voltage generator as instructed in Chapter 10 Section 7.

(h) Set switch MODE OF OPERATION at MANUAL, switch on the azimuth amplidyne and move the antenna off the landmark by 0-20 - 0-25.

Switch off the amplidyne and after it has stopped set the function switch at AUTOMATIC. Use instrument AVO-5 to measure voltage across jacks EXCITATION of the azimuth channel.

Carry out operations outlined in Point "h" every 0-04 - 0-06 as far as 0-20 - 0-25 of mismatch to the other side from the basic position.

Plot the chart of the bearing characteristic curve as the dependence of the azimuth amplidyne excitation voltage in volts upon the azimuth deflection in mils. Plot the slope of the bearing characteristic curve in volts/mils on the straight portion of the chart (Fig.283).

The slope of the bearing characteristic curve is determined by the formula:

$$K_p = K \frac{U_w}{n}$$

where K - the coefficient characterising the landmark selected;

U_w - the excitation voltage drop between two points on the straight portion of the characteristic curve;

n - the number of mils between the two selected points.

Find the magnitude of input signal $U_{input} = K_p$ (0-03) (See Section 4, Subsection "Measuring Amplitude-Frequency Characteristics with System in a Closed State", Point 12 of the present Appendix); the value obtained should be taken as the datum for the initial check of the system in a closed state until the azimuth channel gain is readjusted.

Note: Coefficient K is defined as the relation of the slope of the bearing characteristic with the use of an aircraft, to that measured with the use of the given landmark.

The coefficient value may vary depending upon the landmark selected.

When an aircraft is used to measure the slope of the bearing characteristic it is necessary that the aircraft should hold a straight-line radial course.

Measurements are taken at distances of 8 - 10 km. In this case the current in valve 6KB in the automatic tracking unit is adjusted by AGC potentiometer to 6.5 mA and knob AMPLIFICATION is set at position "5".

To determine the slope of the bearing characteristic with the use of an aircraft it is necessary to operate potentiometer BALANCE to establish 30-40 volts (on each side) across jacks EXCITATION of the azimuth channel.

To measure the mismatch angle, photograph the aircraft through the sight, the number of frames being not less than 25 if unbalancing takes place on both sides.

Calculate the slope of the bearing characteristic, for which purpose divide the set voltage by the average value of the mismatch angle in mils.

3. Description of Meter

Block Diagram of meter

The amplitude-frequency characteristic URAL 2 is comprised of the following elements:

- Sinusoidal oscillation generator M-1;
- Constant speed motor Dw;
- Friction clutch Fr;
- Reducer R;
- Tachogenerator GT;
- Frequency indicator WCz;
- Input signal phase control circuit;
- Input signal amplitude control circuit;
- Output signal phase control circuit;
- Output signal amplitude control circuit;
- Summing amplifier;
- Indicating amplifier;
- Circuits for setting bias of automatic tracking unit AGC valve;
- Adapter.

Input selsyn M-1 is rotated by means of the motor through the friction clutch and reduction gear with constant speed. The rotor of the selsyn is fed with A.C. 24 c.p.s. taken from the reference voltage generator through matching transformer Tr-1.

The input signal which is actually carrier frequency ω modulated by low-frequency sinusoidal oscillations at frequency Ω is fed from selsyn M-1 to the phase shifting circuit. The carrier frequency phase is so selected that the signal injected into the commutator input is in phase with the reference voltage of the channel being examined.

From the output of the phase-shifting circuit the input signal is conducted through the divider to the input of the summing amplifier. The other input of the amplifier is fed with a voltage taken off the output of the selsyn (M32-2 or M32-52) located in the antenna pedestal. These selsyns are fed from transformer Tr-1.

The output voltage of the selsyn (M32-2 or M32-52) i.e. the output signal travels through the phase-shifting circuit and amplitude control circuit.

The summing amplifier output voltage which is essentially the sum of input and output signals, is injected into the input of the antenna positioning system. The signal at the system input equals zero when the input and output signals are equal and opposite in phase. With input selsyn M-1 rotating at angular rate Ω the antenna oscillates sinusoidally with the same frequency Ω.

The rotation frequency of selsyn M-1, i.e. the antenna oscillation frequency, can be continuously controlled by the friction clutch. The frequency-variable reducer can be used to select the frequency variation band within 0 and 1 c.p.s. or 0 and 10 c.p.s.

To change the amplitude of the antenna oscillation use is made of the

input signal whose amplitude is proportional to the antenna oscillation angle. The output signal is measured by the cathode-ray oscillograph and the indicating amplifier.

For measuring amplitude-frequency characteristics of the system in an open state use is made of the same circuit of the meter connection as that for measuring characteristics in a closed state except that the summing amplifier output signal feeding circuit is broken by switch B-3. Thus, the antenna positioning system is open and its input is fed only with an input signal modulated sinusoidally. When measuring the amplitude-frequency characteristics with the system open the antenna angle is measured by the scales of coarse indicators.

Key Circuit Diagram of Amplitude-Frequency Characteristic Meter

The key circuit diagram of the meter is shown in Fig. 285. The meter URAL-2 is fed with voltage from the reference voltage generator through contacts A, B and C of connector Z_w-2. This voltage is then applied through the contacts of switch W-1 AZIMUTH-ELEVATION to step-down transformer Tr-1, which is designed to ......

[one complete page missing]

... one winding is fed directly from 110 V mains, while the other - through capacitor C-6 ensuring the phase shift needed for the motor rotation. Motor M-2 is energized by means of switch W5 MOTOR ON.

The roller position on the friction clutch mushroom may be changed with the help of knob CONTINUOUS FREQUENCY CONTROL, which is accompanied by variation of the speed of the friction clutch output shaft and that of the tachogenerator. The latter is used to measure the assigned frequency. Instrument P_p-1 connected to the tachogenerator output reads the assigned frequency in cycles per second and radians per second. The output shaft of the friction clutch is coupled with the shaft of selsyn M-1 through a reducer with the ratio which can be 10 times increased or decreased which corresponds to the assigned frequency bands from 0 to 1 c.p.s. and from 0 to 10 c.p.s. This switching is done by a frequency band switch.

Knob SELSYN ZERO SETTING is designed to turn the stator of selsyn M-1 by hand which is necessary when setting scales.

Voltages needed for operation of the amplitude-frequency characteristic meter URAL-2 are fed from connector Zw8-1 of the main control board through connector Zw-1 (with the range unit removed).

Pilot lamp Z-1 is used to indicate that supply voltages are applied.

4. Operating Instructions

Connection of Meter

To connect the meter proceed as follows:

- Link connector Zw-1 of the meter with connector Zw8-1 of the main control board and remove the range unit (Fig.286);
- Link connectors Zw-2, Zw-3 and Zw-4 with the adapter by three cables attached to 16-point connector;

- Link the adapter with connector Zw32-1 of the antenna pedestal; the adapter (Fig.287) makes it possible to carry on operation with the station when measuring amplitude-frequency characteristics. For this purpose there is a switch for two positions: STATION and AMPLITUDE-FREQUENCY CHARACTERISTIC. In position STATION all the selsyns are de-energised.

- Link terminals K_2 and K_3 of the meter with jack G6-9 DETECTOR of the automatic tracking units (valve V6-2 must be removed).

Remark: Stations of the first series are not provided with jack G6-9 and with special connector Zw32-1 in the antenna pedestal. When using the meter URAL-2, the following connections should be made; connect:
- terminals K_2 and K_3 of the meter - with lug 3 of the valve V6-2 socket, (remove the valve).
- connector Zw-1 of the meter - with the connector Zw8-1 of the main control board; remove the range unit (timer).
- connector Zw-2 (A, B, C,) - with the terminals P±32-5-1,2,3, of the antenna pedestal.
- connector Zw-4 of the meter - with the fuse holders B13-7 and B13-8 on the control panel (Fig.288).
- connector Zw-3 - with the terminal P±-1 of the adapter (Fig. 17 - see Album).
- connector P±-1 of the adapter with the terminal P±32-1-1;
- connector P±2-10 of the adapter with the terminal P±32-1-6;
- connector P±2-11 of the adapter /T.R. Switch ?/ with the terminal P±32-4-4.

Disconnect the leads connecting antenna pedestal with the terminals: P±32-1-2, P±32-1-3, P±32-1-4, P±32-1-5, P±32-3-10, P±32-4-5 and insert in a correct way the adapter P±2-2 and 3, P±2-4 and 5, P±2-6 and 7, P±2-8 and 9, P±2-14 and 15, P±2-12 and 13.

Measuring amplitude-frequency characteristics with system in open state

1. Switch on the power pack of the range measuring and plan position indicator systems, the automatic tracking unit, the reference voltage generator, selsyns, switch INTERLOCKING located on the antenna control unit.
   Warm up the system for 15 - 20 min. and check the balancing of the azimuth and elevation tracking unit. If the unit is not unbalanced the voltage across jacks EXCITATION should be equal to zero.

2. Set the adapter switch AMPLITUDE-FREQUENCY CHARACTERISTIC - STATION to position STATION.

3. Set the input and output signal switch of the meter URAL-2 to position OFF.

4. Use potentiometer R-22 (BIAS 6K3) of the meter to adjust the current in valve 6K3 of the automatic tracking unit to 6.5 mA.

5. Set switch MODE OF OPERATION of the station at AUTOMATIC.

6. Set control knob AMPLIFICATION of the automatic tracking unit to position "5".

7. Set input signal switch of the meter URAL-2 to position ON.

8. Set switch BAND of the meter to position SELSYN ZERO SETTING.

9. Set switch AZIMUTH-ELEVATION to the AZIMUTH position.

10. Connect voltmeter AVO-5 to jacks EXCITATION of the azimuth channel of the azimuth and elevation tracking unit. Operate knob SELSYN ZERO SETTING of the amplitude-frequency characteristic meter to set the maximum input signal.

11. Connect the oscillograph to jacks COMMUTATOR OUTPUT of the azimuth channel. Operate potentiometer PHASE to establish the phase of the input signal so that the oscillogram on the screen corresponds to a zero phase shift between the error signal and reference voltage (Fig.290)

12. Operate potentiometer RANGE SCALE to set the amplitude of the input signal measuring voltage across jacks EXCITATION of the azimuth channel. The amplitude of the input signal equals the product of the slope of the bearing characteristic and the value of the set signal in mils; the value of the set signal is taken to be 0-03. If the slope of the bearing characteristic $K_p = 4$ V/mil, $U_{input} = K_p \times 3 = 4 \times 3 = 12$ V.
If, with the potentiometer marked RANGE SCALE turned fully clockwise, the desired voltage value cannot be obtained across jacks EXCITATION, it is necessary to isolate the supplies of the selsyns of the azimuth and elevation channel, i.e. to disconnect the lead running to terminal P±32-7-24 (of the current collector) and link terminal P±32-7-24 and connector Zw32-1-12 with a separate wire.

13. Set switch AZIMUTH-ELEVATION of the meter to position ELEVATION.

14. Connect oscillograph to jacks COMMUTATOR OUTPUT of the elevation channel. Use potentiometer PHASE to set the phase of the input signal as outlined in Point 11.

15. Measure the voltage cross jacks EXCITATION of the elevation channel with the help of instrument AVO-5. The value of the bearing characteristic slope (the obtained value divided by 0-03) must be taken as the datum for the subsequent operations on the elevation channel.

16. Set switch BAND to position "0 to 1 c.p.s.".

17. Set switch MOTOR located on the front of the meter to the ON position.

18. Establish the desired value of the set frequency as measured by the frequency indicator using knob CONTINUOUS FREQUENCY VARIATION.

19. Energise the elevation channel amplidyne and set knob FEEDBACK to zero.

20. Read the antenna oscillation amplitude off the scale of the coarse elevation receiving selsyn.
Set knob AMPLIFICATION of the automatic tracking unit so that the antenna oscillation peak-to-peak separation in azimuth may range from 7-50 to 12-50 at the set frequency of 0.4 rd/sec. Record the attained quality factor K and note the position of knob AMPLIFICATION corresponding to it:

$$K_v = 0.0667\ \theta_{output}$$

where θ_{output} - the antenna oscillation peak-to-peak separation, in mils.

21. Set switch MOTOR at position OFF.

22. Set switch AZIMUTH-ELEVATION of the meter to position AZIMUTH.

23. Check the phasing and establish the input signal of the azimuth channel as instructed under Points 11 and 12.

24. Do operations outlined in Points 17, 18.

25. Energise the azimuth channel amplidyne and set knob FEEDBACK of the azimuth channel to zero.

26. Read the antenna oscillation amplitude off the scale of the coarse azimuth receiving selsyn. Measurements are taken with knob AMPLIFICATION in the position described in Point 20. The antenna oscillation peak-to-peak separation in azimuth should be within 15-00 and 22-50. Calculate the quality factor of the azimuth channel as outlined in Point 20.

Note: If the peak-to-peak separation in azimuth is not kept within the assigned range it is necessary to select the values of resistors R10-40, R10-41, R10-44 and R10-45 in the azimuth and elevation tracking unit. To widen the separation the resistances should be increased and vice versa.

After varying the resistances measure the bearing characteristic once again, connect the amplitude-frequency characteristic meter, measure and set the quality factor for the azimuth and elevation channels, and then choose the desired position of knob AMPLIFICATION in the automatic tracking unit.

Measuring amplitude-frequency characteristic with system in closed state

1. Do operations described in Points 1 to 6 of the foregoing subsection.

Note: All measurements should be taken across the azimuth channel jacks. Set the channel switch of the meter URAL-2 to position AZIMUTH.

2. Set the input signal switch of the meter to the OFF position.

3. Set switch STATION - AMPLITUDE-FREQUENCY CHARACTERISTIC to position AMPLITUDE-FREQUENCY CHARACTERISTIC and switch RADAR - WARNING STATION to position WARNING STATION.

4. Set the output signal switch of the meter to the ON position and connect the measuring oscillograph to jack COMMUTATOR OUTPUT of the azimuth and elevation tracking unit.

5. Operate potentiometer PHASE of the meter to match the phase of the output signal as instructed under Point 11 of the foregoing subsection.

6. Set switch MODE OF OPERATION of the station to position MANUAL. Switch on the azimuth channel amplidyne and set switch MODE OF OPERATION at AUTOMATIC. In this case the antenna must follow up the selsyn zero position.

7. Switch off the amplidyne. After it has come to a standstill set switch STATION - AMPLITUDE-FREQUENCY CHARACTERISTIC of the adapter to position STATION and switch RADAR-WARNING STATION to position RADAR.

8. Read the indication on the fine azimuth selsyn scale.

9. Set switch MODE OF OPERATION to position MANUAL. Switch on the amplidyne and move the antenna by means of the manual control handwheel away from the position recorded according to Point 8, by 0-05.

10. Switch off the amplidyne and after it has come to a standstill set switch MODE OF OPERATION of the station to position AUTOMATIC. Set switch RADAR - WARNING STATION to position WARNING STATION and switch STATION - AMPLITUDE-FREQUENCY CHARACTERISTIC to position AMPLITUDE-FREQUENCY CHARACTERISTIC.

11. Match the phase of the output signal as instructed under Point 11 of the foregoing subsection.

12. Operate potentiometer RANGE SCALE (of the output signal) set the output signal equal to the product of the bearing characteristic slope by 0-05 with knob AMPLIFICATION in position "5".

13. Switch the output signal off and the input signal on.

14. Turn knob SELSYN SETTING to set the phase of the input signal differing in phase from that of the output signal by 180° so that the voltage value is at maximum.

15. Match the phase of the input signal as instructed under Point 11 of the foregoing subsection.

16. Operate potentiometer RANGE SCALE (of the input signal) to set the input signal equal to the slope of the bearing characteristic multiplied by 0-05.

17. Switch on the output signal; the voltage across jacks EXCITATION must drop to zero; if it exceeds 1 V check the balancing of the azimuth and elevation tracking unit, phase and range setting of the input and output signals.

18. Connect the oscillograph to terminals OSCILLOGRAPH of the meter URAL-2. Set knob DIVIDER I and DIVIDER II to position "0" on the scale. Adjust the oscillograph gain to obtain the signal amplitude suitable for measurements (30-40 mm) on the tube screen.

19. Set knob AMPLIFICATION of the automatic tracking unit to the position chosen in Points 20, 26 of the foregoing sub-section.

20. Switch on the amplidyne.

21. Set the BAND switch to the required position.

22. Switch on the motor of the meter URAL-2.

23. Set the required frequency by means of knob CONTINUOUS VOLTAGE VARIATION.

24. Switch on DIVIDER I if the amplitude of the signal on the measuring oscillograph has increased, or DIVIDER II, if the amplitude has decreased. By turning the knob of the appropriate divider make so that the signal amplitude on the measuring oscillograph acquires the value indicated in Point 18.

25. Read the value of the system gain off the divider scale with due allowance for corrections (refer to divider calibration correction charts supplied with the meter).

26. Perform operations mentioned in Points 23, 24, 25 and measure the gain

at frequencies: 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, 5.5, 6.0, 7, 8, 9 rd/sec.

Notes: 1. When measuring the amplitude-frequency characteristic of the elevation channel take all measurements across the jacks of this channel. Set the channel switch of the meter URAL-2 to position ELEVATION. The antenna position in elevation must be within 6-00 and 7-00; the value of the bearing characteristic slope is taken in accordance with Point 15 of the foregoing subsection of the present Appendix.

2. When measuring the characteristic give special attention to the accurate setting of the range scales of the input and output signals, to accurate measurement of the bearing characteristic and to determination of new values of the slope when varying shunting resistance R10-40, R10-41, R10-44 and R10-45 in the azimuth and elevation tracking unit.

27. Set knob FEEDBACK in such a way that the peak of the amplitude-frequency characteristic is not greater than 6 db, the pass band is within 5 and 8 rd/sec. for the azimuth channel and within 3 and 6 rd/sec. for the elevation channel (in respect of the decibel zero level, Fig. 282).

Appendix 4

SPECIFICATION TO KEY DIAGRAMS OF UNITS OF THE SON-9 STATION

Circuit designation	Name and type	Main data, rating	Notes
	Transmitting System		
	Driver		
R23-1	Resistor WS-0.25-1-390-II	390 ohms	10 kilohms in the stations of the first series
R23-2	Resistor WS-1-1-7500-1	7.5 kilohms	
R23-4	Resistor WS-0.25-1-0.15-II	0.15 megohm	
R23-5	Resistor WS-2-1-10000-II	10 kilohms	
R23-6	Resistor WS-1-1-4700-II	4.7 kilohms	
R23-7	Resistor WS-2-1-7500-II	7.5 kilohms	
R23-8	Resistor WS-2-1-0.1-II	0.1 megohm	
R23-9	Resistor WS-0.5-1-47000-II	47 kilohms	
R23-10	Resistor PEW-50-7.5-kilohm-II	7.5 kilohms	
R23-11	Resistor WS-2-1-4700-II	4.7 kilohms	
R23-12	Resistor WS-2-1-33000-II	33 kilohms	
R23-13	Resistor WS-1-1-51-II	51 ohms	
R23-14	Resistor WS-1-1-51-II	51 ohms	
R23-15	Resistor, wire-wound, non-inductive, 5 W; 10 ohms ± 10%	10 ohms	
R23-16	Resistor, wire-wound, non-inductive, 5 W; 10 ohms ± 10%	10 ohms	
R23-17	Resistor WS-2-1-56-II	56 ohms	
R23-18	Resistor WS-1-1-51-II	51 ohms	
R23-19	Resistor WS-1-1-51-II	51 ohms	
R23-20	Resistor, wire-wound, non-inductive, 5 W; 10 ohms ± 10%	10 ohms	
R23-21	Resistor, wire-wound, non-inductive, 5 W; 10 ohms ± 10%	10 ohms	
R23-22	Resistor WS-1-1-51-II	51 ohms	
R23-23	Resistor WS-1-1-51-II	51 ohms	
R23-24	Resistor WS-1-1-51-II	51 ohms	
R23-25	Resistor WS-1-1-51-II	51 ohms	
R23-26	Resistor, wire-wound, non-inductive, 5 W; 10 ohms ± 10%	10 ohms	
R23-27	Resistor, wire-wound, non-inductive, 5 W; 10 ohms ± 10%	10 ohms	
R23-28	Resistor PEW-50-5.1 kilohm II	5.1 kilohms	
R23-29	Resistor PEW-30-3.6 kilohm II	3.6 kilohms	
R23-30	Resistor WS-2-1-1000-II	1 kilohm	
R23-31	Resistor WS-2-1-1000-II	1 kilohm	There is no R23-31 in the stations of the first series.
R23-32	Resistor PEW-50-7.5 kilohm II	7.5 kilohms	
R23-33	Resistor WS-2-1-5600-II	5.6 kilohms	
R23-24	Resistor WS-2-1-10000-II	10 kilohms	
R23-35	Resistor PEW-20-3 kilohm-II	1 kilohm	
R23-36	Resistor WS-2-1-0.62-II	0.62 megohm	
R23-37	Resistor WS-2-1-1-II	1 megohm	
R23-38	Resistor WS-2-1-0.39-II	0.39 megohms	
R23-39	Resistor WS-2-1-3900-II	3.9 kilohms	
R23-40	Resistor WS-2-1-2200-II	2.2 kilohms	
R23-41	Resistor WS-2-1-10000-II	10 kilohms	

/.........

C23-1	Capacitor KTK-1-M-20-II	20 pF	
C23-2	Capacitor KTK-1-2-10-II	10 pF	
C23-3	Capacitor KSO-5-500-B-3000-I	3000 pF	
C23-4	Capacitor KSO-5-500-B-3000-I	3000 pF	
C23-5	Capacitor KSO-7-1000-B-3000-I	3000 pF	
C23-6	Capacitor KBG-M2-400-0.25-II	0.25 µF	
C23-7	Capacitor KBG-MN-2A-600-2.0-II	2 µF	
C23-8	Capacitor KBG-P-2-4-0.5-II	0.5 µF	
C23-9	Capacitor KSO-12-5000-A-100-I	100 pF	
C23-10	Capacitor KTK-2-M-47-I	47 pF	
C23-11	Capacitor KTK-2-M-47-I	47 pF	
C23-12	Capacitor KTK-2-M-47-I	47 pF	
C23-13	Capacitor KTK-2-M-47-I	47 pF	
C23-14	Capacitor KBG-MN-2A-400-2.0-II	2 µF	
C23-15	Capacitor KBG-MN-2A-400-1.0-II	1 µF	
C23-16	Capacitor KBG-MN-2A-600-2.0-II	2 µF	
C23-17	Capacitor KBG-MN-2A-600-2.0-II	2 µF	
C23-18	Capacitor KBG-MN-2A-1000-1.0-II	1 µF	
C23-19	Capacitor KTK-2-M-47-II	47 pF	
C23-20	Capacitor KBG-MN-2A-400-1.0-II	1 µF	
C23-21	Capacitor KBG-MN-2A-1500-1.0-II	1 µF	
C23-22	Capacitor KTK-2-M-47-I	47 pF	
C23-23	Capacitor KTK-2-M-47-I	47 pF	
C23-24	Capacitor KTK-2-M-47-I	47 pF	
C23-25	Capacitor KTK-2-M-47-I	47 pF	
L23-1	Choke	1 MH	
L23-2	Choke	2.1 MN	
L23-3	Choke	0.96 MN	
V23-1	Double triode 6N8S		
V23-2	Beam tetrode 6P3S		
V23-3	Double beam tetrode GI30		
V23-4	Double beam tetrode GI-30		
V23-5	Double beam tetrode GI-30		
V23-6	Kenotron 5C4S		
V23-7	Kenotron 5C4S		
V23-8	Kenotron 5C4S		
Tr23-1	Transformer	790 V/320 V	
Tr23-2	Transformer	3200 V/2700 V	
Tr23-3	Transformer	110 V/2x190 V 5 V; 427 c/s	
Tr23-4	Transformer	110 V/2x450 V 2x240 V; 427 c/s	
Tr23-5	Transformer	110 V/5 V; 5V; 6.3 V; 200 V; 427 c/s	
Dł23-1	Choke 1.5 H + 50% - 10%	1.5 H, 75 mA	
Dł23-2	Choke 1.5 H + 50% - 10%	1.5 H, 75 mA	
P23-1	Relay, double-pole, unidirectional	20 mA	Not in the stations of the first series.
B23-1	Fuse	3 A	
B23-2	Fuse	3 A	
Zw23-1	Connector	16 contact	
Zw23-2	Connector	1 contact	
Zw23-6	Connector	1 contact	
Zw23-7	Connector	1 contact	

Modulator-oscillator

R25-1	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-2	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-3	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-4	Resistor WS-2-1-0.62-II	0.62 megohms	

R25-5	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-6	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-7	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-8	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-9	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-10	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-11	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-12	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-13	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-14	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-15	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-16	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-17	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-18	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-19	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-20	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-21	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-22	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-23	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-24	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-25	Resistor WS-2-1-0.62-II	0.62 megohms	
R25-26	Resistor SP-II-1a-470B	470 kilohms	
R25-27	Resistor SP-II-1a-470B	470 kilohms	
R25-28	Resistor SP-II-1a-470B	470 kilohms	
R25-29	Resistor SP-II-1a-470B	470 kilohms	
R25-30	Resistor SP-II-1a-470B	470 kilohms	
R25-31	Resistor PEW-25-390-II	390 ohms	
R25-32	Resistor PEW-25-390-II	390 ohms	
R25-33	Resistor WS-1-1-51-II	51 ohms	
R25-34a	Resistor WS-1-1-470-II	470 ohms	
R25-34b	Resistor WS-1-1-470-II	470 ohms	
R25-35	Resistor, tubular, VI-5000 ± 10%	5 kilohms	
R25-36	Resistor, tubular, VI-5000 ± 10%	5 kilohms	
R25-37	Resistor, tubular, VI-25000 ± 5%	25 kilohms	
R25-38	Resistor, tubular, VI-40000 ± 5%	40 kilohms	
R25-39	Resistor WS-2-1-3-II	3 megohms	
R25-40	Resistor, wire-wound, non-inductive, 8 W, 10 ohms ± 10%	10 ohms	
R25-41	Resistor, wire-wound, non-inductive, 8 W, 10 ohms ± 10%	10 ohms	
R25-42	Resistor, wire-wound, non-inductive, 8 W, 10 ohms ± 10%	10 ohms	
R25-43	Resistor, wire-wound, non-inductive, 5 W, 10 ohms ± 10%	10 ohms	
R25-44	Resistor, wire-wound, non-inductive, 5 W, 10 ohms ± 10%	10 ohms	
R25-45	Resistor, wire-wound, non-inductive, 5 W, 10 ohms ± 10%	10 ohms	
R25-46	Resistor WS-2-1-1-II	1 megohm	
R25-47	Resistor, tubular, VI-200 ±10%	200 ohms	
R25-48	Resistor WS-2-1-1-II	1 megohm	
R25-49	Resistor WS-2-1-1-II	1 megohm	
R25-50	Resistor WS-2-1-1-II	1 megohm	
R25-51	Resistor WS-2-1-1-II	1 megohm	
R25-52	Resistor WS-2-1-1-II	1 megohm	
R25-53	Resistor WS-2-1-1-II	1 megohm	
R25-57	Resistor WS-2-1-0.1-II	0.1 megohm	
R25-58	Resistor WS-2-1-1-II	1 megohm	
R25-59	Resistor PEW-50-20-II	20 kilohms	
R25-60	Resistor, special, 7-11 kilohms	7-11 kilohms)	Not in the
R25-61	Resistor WS-2-1-0.62-II	0.62 megohms)	stations of
R25-62	Resistor WS-2-1-4.7-II	4.7 megohms)	the first
R25-63	Resistor WS-2-1-2-II	2 megohms)	series.

C25-1	Capacitor KBG-MN-2A-1500-2.0-III	2 µF	
C25-2	Capacitor KSO-12-5000-A-15-II	15 pF	
C25-3	Capacitor KSO-12-5000-A-39-II	39 µF	
C25-4	Capacitor KBG-I-600-0.01-II	10000 pF	
C25-5	Capacitor RL-27.0-0.125 (+ 20% - 10%)	0.125 µF	
C25-6	Capacitor KBG-MN-2A-1500-2.0-III	2 µF	
C25-7	Capacitor KSO-7-2500-A-100-II	100 pF	
C25-8	Capacitor KBG-P-2-4-1.0-III	1 µF	
C25-9	Capacitor RL-32.5-0.25 (+20% -10%)	0.25 µF	With two insulated leads.
C25-10	Capacitor RL-32.5-0.25 (+20% -10%)	0.25 µF	With one insulated lead.
C25-11	Capacitor KBG-MP-2W-1000-01-II	0.1 µF	
C25-12	Capacitor KBG-MP-2W-1000-0.1-II	0.1 µF	
C25-13	Capacitor KBG-MP-2W-1000-0.1-II	0.1 µF	
C25-17	Capacitor KBG-I-600-0.01-II	10000 pF	
C25-18	Capacitor KBG-I-600-0.01-II	10000 pF	Not in the stations of the first series.
C25-19	Capacitor KBG-MN-2A-200-2.0-II	2 µF	
L25-1	Choke	2.5 MH	
L25-2	Choke	5 MH	
V25-1	Pulse triode GMI-30		
V25-2	Pulse triode GMI-30		
V25-3	Pulse triode GMI-30		
V25-4	Kenotron W1-0.1/40		
V25-5	Kenotron W1-0.1/40		
V25-6	Kenotron W1-0.1/40		
V25-7	Magnetron MI-18-21		
V25-8	Kenotron VU-111-D		
V25-9	Kenotron VU-111-D		
V25-10	Kenotron VU-111-D		
V25-11	Kenotron W1-0.1/40		
V25-12	Kenotron W1-0.1/40		
N25-13	Neon lamp MN-3		
N25-14	Neon lamp MN-3		
N25-15	Neon lamp MN-3		
N25-16	Neon lamp MN-3		
ZG25-18	Gas discharger 4378-D		
ZG25-19	Gas discharger 4378-D		
Z25-20	Dial lamp, type 15		
Z25-21	Dial lamp, type 15		
Z25-22	Dial lamp, type 15		
V25-23	Double triode 6N8S		Not in the stations of the first series.
Tr25-1	Transformer	220 V/8.2 V; 50 c/s	
Tr25-2	Transformer	220 V/5.3 V; 50 c/s	
Tr25-3	Transformer	110 V/6.3 V; 427 c/s	
Tr25-4	Transformer	110 V/2x3200V 427 c/s	
Tr25-5	Transformer	110 V/4 V; 427 c/s	
Tr25-6	Transformer	110 V/12 V; 740 V; 427 c/s	
Tr25-7	Potential regulator	0-100 V; 427 c/s	An auto-transformer in the stations of the first series.

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Tr25-8	Transformer	110 V/5 V; 5 V; 427 c/s	
Tr25-9	Transformer	110 V/1120 V; 427 c/s	
Tr25-10	Transformer	110 V/4 V; 427 c/s	
W25-1	Switch	25 A	
W25-2	Start button		
W25-3	Start button	5 positions	
W25-4	Switch		
W25-5	Interlock		
W25-6	Interlock		
W25-7	Interlock		
W25-8	Interlock		
W25-9	Interlock		
W25-10	Interlock		
Pp25-1	Kilovoltmeter		
Pp25-2	Milliammeter M-52		
Pp25-3	Milliammeter M-52		
P25-1	Magnetic starter MPKO-111		
P25-2	Magnetic starter MPKO-111		
P25-3	Minimum relay	20 mA	
P25-4	Maximum relay	40 mA	
P25-5	Maximum relay	80 mA	
P25-6	Time relay, delay within 0-300 sec.	220 V; 50 c/s	In the stations of the latest series, it is replaced by an electronic relay.
P25-7	Discharging relay	220 V; 50 c/s	
P25-8	Minimum relay	20 mA	
P25-9	Minimum relay	20 mA	
M25-1	Motor AOL-21-2,220 V,three-phase	2800 r.p.m.	
M25-2	Fan motor in the transmitter cabinet		
PB25-1	Spark discharger		Not in the stations of the first series.
PB25-2	Spark discharger		
PB25-3	Spark discharger		
B25-1	Fuse	25 A	
B25-2	Fuse	25 A	
B25-3	Fuse	10 A	
B25-4	Fuse	10 A	
B25-5	Fuse	10 A	
B25-6	Fuse	5 A	Not in the stations of the latest series. This code number designates a fuse of 3 A.
B25-7	Fuse	5 A	
B25-8	Fuse	15 A	
B25-9	Fuse	15 A	
B25-10	Fuse	3 A	Not in the stations of the first series.
Pl25-1	Terminal block	4-terminal	
Pl25-2	Terminal block	4-terminal	
Pl25-5	Terminal block	10-terminal	
Zw25-1	Connector	16-contact	
Zw25-2	Connector	1-contact	
Zw25-3	Connector	1-contact	
Zw25-4	Connector	1-contact	
Zw25-5	Connector	1-contact	
Zw25-6	Connector	1-contact	
Zw25-7	Connector	1-contact	

Zw25-9	Connector	10-contact
Zw25-10	Connector	3-contact
U25-1	Permanent magnet	

Receiving system

I-F Preamplifier unit

R22-1	Resistor WS-0.25-1-330-II	330 ohms
R22-2	Resistor WS-0.25-1-100-II	100 ohms
R22-3	Resistor WS-0.25-1-100-II	100 ohms
R22-4	Resistor WS-0.25-1-100-II	100 ohms
R22-5	Resistor WS-0.25-1-330-II	330 ohms
R22-6	Resistor WS-0.25-1-510-II	510 ohms
R22-7	Resistor WS-0.25-1-100-II	100 ohms
R22-8	Resistor WS-0.25-1-330-II	330 ohms
R22-9	Resistor WS-0.25-1-510-II	510 ohms
R22-10	Resistor WS-0.25-1-100-II	100 ohms
R22-11	Resistor WS-0.25-1-330-II	330 ohms
R22-12	Resistor WS-0.25-1-3900-II	3.9 kilohms
R22-13	Resistor WS-0.25-1-10000-II	10 kilohms
R22-14	Resistor WS-0.25-1-0.1-II	0.1 megohm
R22-15	Resistor WS-0.25-1-0.1-II	0.1 megohm
R22-16	Resistor WS-0.25-1-0.51-I	0.51 megohm
R22-17	Resistor WS-0.25-1-10000-II	10 kilohms
R22-18	Resistor WS-0.5-1-18000-II	18 kilohms
R22-19	Resistor WS-1-1-0.39-II	0.39 megohms
R22-20	Resistor WS-0.5-1-1.8-II	1.8 megohms
R22-21	Resistor WS-0.5-1-1.2-II	1.2 megohms
R22-22	Resistor WS-0.25-1-3000-I	3 kilohms
R22-23	Resistor WS-0.5-1-1.8-II	1.8 megohms
R22-24	Resistor WS-0.5-1-1.8-II	1.8 megohms
R22-25	Resistor WS-0.5-1-22000-II	22 kilohms
R22-26	Resistor WS-0.5-1-0.22-II	0.22 megohms
R22-27	Resistor WS-1-1-0.1-II	0.1 megohms
R22-28	Resistor WS-0.25-1-100-II	100 ohms
R22-29	Resistor WS-0.25-1-100-II	100 ohms
R22-30	Resistor WS-1-1-0.1-II	0.1 megohm
R22-31	Resistor WS-0.25-1-200-I	200 ohms
R22-32	Resistor WS-0.25-1-330-II	330 ohms
R22-33	Resistor WS-0.25-1-200-I	200 ohms
R22-34	Resistor WS-0.25-1-330-II	330 ohms
R22-35	Resistor WS-0.25-1-680-II	680 ohms
R22-36	Resistor WS-1-1-820-II	820 ohms
R22-37	Resistor WS-0.25-1-100-I	100 ohms
R22-38	Resistor WS-0.25-1-1000-II	1 kilohm
R22-39	Resistor WS-0.25-1-330-II	330 ohms
R22-40	Resistor PEW-20-3 kilohms-II	3 kilohms
R22-41	Resistor WS-1-1-18000-II	18 kilohms
R22-42	Resistor PEW-20-510 ohms-II	510 ohms
R22-43	Resistor WS-1-1-0.18-II	0.18 megohms
R22-44	Resistor WS-0.25-1-100-II	100 ohms
R22-45	Resistor WS-1-1-0.47-II	0.47 ohms
R22-46	Resistor WS-0.25-1-22000-II	22 kilohms
R22-47	Resistor WS-2-1-4700-II	4.7 kilohms
R22-48	Resistor WS-2-1-10000-II	10 kilohms
R22-49	Resistor WS-0.25-1-47000-II	47 kilohms
R22-50	Resistor SP-II-2a-47 A	47 kilohms
R22-51	Resistor WS-0.25-1-0.1-II	0.1 megohm
R22-52	Resistor PO-20-15 kilohms-II	15 kilohms
R22-53	Resistor PO-20-15 kilohms-II	15 kilohms
R22-54	Resistor WS-0.5-1-1-II	1 megohm
R22-55	Resistor WS-1-1-0.1-II	0.1 megohm

R22-57	Resistor SP-1-2a-100 A 13 1	0.1 megohm
R22-58	Resistor WS-0.5-1-1-II	1 megohm
R22-59	Resistor SP-II-2a-470 A	0.47 megohm
R22-60	Resistor WS-0.5-1-1.8-II	1.8 megohms
R22-61	Resistor WS-0.25-1-100-II	100 ohms
R22-62	Resistor PEW-20-3 kilohms-II	3 kilohms
R22-63	Resistor SP-II-2a-1 A	1 kilohm
R22-64	Resistor WS-1-1-51000-I	51 kilohms
C22-1	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-2	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-3	Capacitor KPK-1-2-7	2 - 7 pF
C22-4	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-5	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-6	Capacitor KSO-2-500-B-100-II	100 pF
C22-7	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-8	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-9	Capacitor KSO-2-500-B-100-II	100 pF
C22-10	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-11	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-12	Capacitor KPK-1-4-15	4 - 15 pF
C22-13	Capacitor KTK-1-M-22-II	22 pF
C22-14	Capacitor KPK-1-2-7	2 - 7 pF
C22-15	Capacitor KTK-2-M-47-II	47 pF
C22-16	Capacitor KTK-1-M-22	22 pF
C22-17	Capacitor KBG-1-200-0.05-II	0.05µ F
C22-18	Capacitor KSO-5-500-B-5100-II	5100 pF
C22-19	Capacitor KBG-1-200-0.1-II	0.1 µF
C22-20	Capacitor KBG-MP-2B-1000-0.5-II	0.05 µF
C22-21	Capacitor KSO-5-500-B-3000-II	3000 pF
C22-22	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-23	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-24	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-25	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-26	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-27	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-28	Capacitor KSO-2-500-B-100-II	100 pF
C22-29	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-30	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-31	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-32	Capacitor KSO-2-500-B-150-II	150 pF
C22-33	Capacitor KSO-2-500-B-100-II	100 pF
C22-34	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-35	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-36	Capacitor KBG-MN-2A-400-2x2.0-II	2x2.0 µF
C22-37		
C22-38	Capacitor KBG-MP-W-600-0.5-II	0.5 µF
C22-39	Capacitor KBG-MN-2A-600-2.0-III	2.0 µF
C22-40	Capacitor KBG-MN-2A-600-2.0-III	2.0 µF
C22-41	Capacitor KBG-MN-2A-600-2.0-III	2.0 µF
C22-42	Capacitor KBG-MN-2A-400-2.0-III	2.0 µF
C22-43	Capacitor KBG-MP-2A-400-0.25-II	0.25 µF
C22-44	Capacitor KSO-5-500-B-5100-II	5100 pF
C22-45	Capacitor KBG-I-600-0.01-II	0.01 µF
C22-46	Capacitor KBG-MP-W-600-0.5-II	0.5 µF
C22-47	Capacitor KBG-MP-W-600-1.0-III	1.0 µF
C22-48	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-49	Capacitor KSO-2-500-B-1000-II	1000 pF
C22-50	Capacitor KSO-2-500-B-1000-II	1000 pF
L22-1	Choke	5 µH
L22-2	Choke	5 µH
L22-3	Induction coil	1.4 µH
L22-4	Induction coil	1.4 µH
L22-5	High-frequency choke	50 µH

L22-6	High-frequency choke	1.6 µH	
L22-7	High-frequency choke	5 µH	
L22-8	High-frequency choke	5 µH	
L22-9	High-frequency choke	1.6 µH	
L22-10	Induction coil	4 µH	
L22-11	Induction coil	2.4 µH	
L22-12	Induction coil	22 µH	
L22-13	Induction coil	1.75 µH	
L22-14	Induction coil	4 µH	
Dł22-1	Low-frequency choke	5 H	
Tr22-1	High-frequency transformer		
Tr22-2	Discriminator tank circuit		
Tr22-3	Transformer	110 V/2x287 V/ 5 V, 6.3 V 427 c/s	
Tr22-4	Transformer	110 V/2x500 V 427 c/s	
Tr22-5	Transformer	110 V/5 V/5 V/ 6.3 V/6.3 V/ 6.3 V/6.3 V 427 c/s	
Zw22-1	High-frequency cable connector		
Zw22-2	High-frequency cable connector		
Zw22-3	High-frequency connector		
Zw22-4	High-frequency connector		
Zw22-5	Knife-type connector	10-contact	
Zw22-6	High-frequency connector		
Zw22-7	High-frequency connector		
G22-1	Telephone jack		
G22-2	Telephone jack		
W22-1	Double-pole switch		
W22-2	Double-pole switch		
W22-3	Double-pole switch 3P3N		
W22-4	Double-pole switch 3P3N		
B22-1	Fuse	3 A	
B22-2	Fuse	1 A	
Pp22-1	Milliammeter PMS-O-1 mA		
V22-1	Valve 6Z4		
V22-2	Valve 6Z4		
V22-3	Valve 6Z4		
V22-4	Valve 6H6S		
V22-5	Valve 6Z4		
V22-6	Valve 6H6S		
V22-7	Valve 6Z4		
V22-8	Valve 6Z1P		
V22-9	Valve 6Z1P		
V22-10	Valve 6Z4		
V22-11	Valve 5C4S		
V22-12	Valve SG4S		
V22-13	Neon lamp MN-3		
V22-14	Valve 5C4S		
V22-15	Neon lamp MN-3		
V22-16	Valve 6P3S		
V22-17	Valve SG4S		
V22-18	Valve 6Z8		
V22-19	Valve 5C4S		
V22-20	Valve SG3S		
V22-21	Valve SG4S		
V22-22	Klystron K-11		
V22-23	Lamp MN-15	6.3 V;0.25A	

SECRET

Amplifier unit of automatic tracking channel

R1-1	Resistor WS-0.25-1-75-II	75 ohms
R1-2	Resistor WS-0.25-1-330-II	330 ohms
R1-3	Resistor WS-0.25-1-100-II	100 ohms
R1-4	Resistor WS-0.25-1-470-II	470 ohms
R1-5	Resistor WS-0.25-1-330-II	330 ohms
R1-6	Resistor WS-0.25-1-330-II	330 ohms
R1-7	Resistor WS-0.25-1-470-II	470 ohms
R1-8	Resistor WS-0.25-1-100-II	100 ohms
R1-9	Resistor WS-0.25-1-330-II	330 ohms
R1-10	Resistor WS-0.25-1-100-II	100 ohms
R1-11	Resistor WS-0.25-1-470-II	470 ohms
R1-12	Resistor WS-0.25-1-330-II	330 ohms
R1-13	Resistor WS-0.25-1-330-II	330 ohms
R1-14	Resistor WS-0.25-1-470-II	470 ohms
R1-15	Resistor WS-0.25-1-100-II	100 ohms
R1-16	Resistor WS-0.25-1-56-II	56 ohms
R1-17	Resistor WS-0.25-1-270-II	270 ohms
R1-18	Resistor WS-0.25-1-330-II	330 ohms
R1-19	Resistor WS-0.5-1-1000-I	1 kilohm
R1-20	Resistor WS-0.5-1-100-II	100 ohms
R1-21	Resistor SP-11-2a-I A	1 kilohm
R1-22	Resistor WS-0.25-1-100-II	100 ohms
R1-23	Resistor WS-0.5-1-1000-I	1 kilohm
R1-24	Resistor WS-0.25-1-330-II	330 ohms
R1-25	Resistor WS-1-1-62000-II	62 kilohms
R1-26	Resistor WS-0.25-1-4300-I	4.3 kilohms
R1-27	Resistor WS-0.25-1-2000-II	2 kilohms
R1-28	Resistor WS-0.25-1-220-II	220 ohms
R1-29	Resistor WS-0.25-1-1000-I	1 kilohm
R1-30	Resistor WS-2-1-4300-II	4.3 kilohms
R1-31	Resistor WS-2-1-6800-II	6.8 kilohms
R1-33	Resistor WS-0.25-1-0.24-II	0.24 megohms
R1-34	Resistor WS-1-1-1000-II	1 kilohm
R1-35	Resistor WS-2-1-1500-II	1.5 kilohms
R1-37	Resistor WS-0.25-1-4700-II	4.7 kilohms
R1-38	Resistor WS-0.25-1-0.1-II	0.1 megohm
R1-39	Resistor WS-0.25-1-0.1-II	0.1 megohm
R1-40	Resistor WS-0.25-1-33000-II	33 kilohms
R1-41	Resistor WS-2-1-18000-II	18 kilohms
R1-42	Resistor SP-II-2a-3.3 A	3.3 kilohms
R1-43	Resistor WS-1-1-82000-II	82 kilohms
R1-44	Resistor SP-1-2a-10 A	10 kilohms
R1-45	Resistor WS-0.5-1-1.5-II	1.5 megohms
R1-46	Resistor WS-0.5-1-4.7-II	4.7 megohms
R1-47	Resistor WS-0.5-1-1000-II	1 kilohm
R1-48	Resistor WS-2-1-0.1-II	0.1 megohm
R1-49	Resistor WS-1-1-0.33-II	0.33 megohm
R1-50	Resistor WS-0.5-1-56000-II	56 kilohms
R1-51	Resistor WS-2-1-39000-II	39 kilohms
R1-52	Resistor WS-2-1-39000-II	39 kilohms
R1-53	Resistor WS-2-1-0.47-II	0.47 megohm
R1-54	Resistor SP-II-2a-100 A	0.1 megohm
R1-55	Resistor WS-0.25-1-0.1-II	0.1 megohm
R1-56	Resistor WS-0.25-1-0.51-II	0.51 megohm
R1-57	Resistor WS-1-1-33000-II	33 kilohms
R1-58	Resistor WS-0.25-1-330-II	330 ohms
R1-59	Resistor WS-0.25-1-100-II	100 ohms
R1-60	Resistor WS-2-1-0.1-II	0.1 megohm
R1-61	Resistor WS-0.25-1-10000-II	10 kilohms

SECRET

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C1-1	Capacitor KTK-2-D-100-II	100 pF	
C1-2	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-3	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-5	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-6	Capacitor KTK-2-D-100-II	100 pF	
C1-7	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-8	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-9	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-10	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-11	Capacitor KTK-2-D-100-II	100 pF	
C1-12	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-14	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-15	Capacitor KTK-2-D-100-II	100 pF	
C1-16	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-18	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-19	Capacitor KBG-I-200-0.05-II	0.05 µF	
C1-20	Capacitor KTK-2-D-100-II	100 pF	
C1-21	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-22	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-23	Capacitor KSO-2-500-B-5100-II	5100 pF	
C1-24	Capacitor KTK-2-D-240-I	240 pF	
C1-25	Capacitor KTK-2-D-100-II	100 pF	
C1-26	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-27	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-29	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-31	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-32	Capacitor KTK-I-M-5-II	5 pF	
C1-33	Capacitor KTK-2-D-100-II	100 pF	
C1-35	Capacitor KBG-MP-2W-600-2x0.5-II	2x0.5 µF	
C1-36	Capacitor KBG-MP-2W-600-2x0.5-II	2x0.5 µF	
C1-37	Capacitor KSO-5-500-B-5100-II	5100 pF	
C1-39			
C1-40	Capacitor KBG-I-400-0.05-II	0.05 µF	
C1-41	Capacitor KSO-5-500-B-5100-II	5100 pF	
C1-42	Capacitor KBG-MP-2W-600-2x0.5-II	2x0.5 µF	
C1-43	Capacitor KBG-I-200-0.1-II	0.1 µF	
C1-44	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-45	Capacitor KBG-MP-N-200-0.1-II	1.0 µF	
C1-47	Capacitor KBG-MN-2A-400-2x2.0-II	2x2.0 µF	
C1-48	Capacitor KBG-MN-2A-400-2x2.0-II	2x2.0 µF	
C1-50	Capacitor KBG-MP-W-600-0.5-II	0.5 µF	
C1-51	Capacitor KSO-5-500-B-5100-II	5100 pF	
C1-52	Capacitor KBG-MP-W-400-0.25-II	0.25 µF	
C1-53	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-54	Capacitor KSO-2-500-B-1000-II	1000 pF	
C1-55	Capacitor KSO-2-500-B-1000-II	1000 pF	
L1-1	Induction coil	2.9 µH	
L1-2	Induction coil	1.4 µH	
L1-3	Induction coil	1.4 µH	
L1-4	Induction coil	1.4 µH	
L1-5	Induction coil	0.95 µH	
L1-6	Induction coil	1.4 µH	
L1-7	Induction coil	2.4 µH	
L1-8	Choke	90 µH	
L1-9	Choke	1 µH	
L1-10	Induction coil	3.25 µH	
L1-11	Choke	200 µH	
Tr1-1	Transformer	110 V/2x300 V 427 c/s	
Tr1-2	Transformer	110 V/5 V/ 6.3 V/6.3 V/ 6.3 V/12.6 V 427 c/s	

V1-1	Valve 6Z4		
V1-2	Valve 6Z4		
V1-3	Valve 6Z4		
V1-4	Valve 6Z4		
V1-5	Valve 6Z4		
V1-6	Valve 6Z4		
V1-7	Valve 6H6S		
V1-8	Valve 6Z4		
V1-9	Valve 6P9		
V1-10	Valve 6N8S		
V1-11	Valve 6Z4		
V1-12	Valve 5C4S		
V1-13	Valve GU-50		
V1-14	Valve 6P9		
V1-15	Valve SG3S		
V1-17	Neon lamp MN-3		
Zw1-1	High-frequency connector		
Zw1-2	Connector		
Zw1-3	High-frequency connector		
Zw1-4	High-frequency connector		
Zw1-5	High-frequency connector		
Zw1-6	Knife-type connector	10-contact	
G1-1	Jack		
G1-2	Telephone jack		
G1-3	Telephone jack		
G1-4	Telephone jack		
W1-1	Double-pole switch		
W1-2	Double-pole switch		
W1-3	Plug		
B1-1	Fuse	2 A	
B1-2	Fuse	1 A	
Dł1-1	Choke	90 mA; 0.5	
P1-1	Double-pole two-way relay	110 V; 50 c/s	

Range Channel Amplifier

R2-1	Resistor WS-0.25-1-200-II	200 ohms	
R2-2	Resistor WS-0.25-1-56-II	56 ohms	
R2-3	Resistor SP-II-2a-1A	1 kilohm	
R2-4	Resistor WS-0.25-1-680-II	680 ohms	
R2-5	Resistor WS-1-1-1500-II	1.5 kilohm	
R2-6	Resistor WS-1-1-62000-II	62 kilohms	
R2-7	Resistor WS-0.25-1-2000-I	2 kilohms	
R2-8	Resistor WS-0.25-1-200-II	200 ohms	
R2-9	Resistor WS-0.25-1-75000-I	75 kilohms	
R2-10	Resistor WS-0.25-1-3000-I	3 kilohms	
R2-11	Resistor WS-0.25-1-0.22-II	0.22 megohm	
R2-12	Resistor WS-1-1-2000-I	2 kilohms	
R2-13	Resistor WS-2-1-56000-II	56 kilohms	
R2-14	Resistor WS-2-1-24000-II	24 kilohms	
R2-15	Resistor WS-1-1-2700-II	2.7 kilohms	
R2-16	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R2-17	Resistor WS-0.25-1-150-II	150 ohms	
R2-18	Resistor WS-0.25-1-10000-II	10 kilohms	
R2-19	Resistor WS-0.25-1-7500-I	7.5 kilohms	
R2-20	Resistor WS-0.25-1-33000-II	33 kilohms	
R2-21	Resistor WS-2-1-1000-II	1 kilohm	
R2-22	Resistor WS-2-1-1000-II	1 kilohm	
R2-23	Resistor WS-2-1-1000-II	1 kilohm	
R2-24	Resistor WS-2-1-1000-II	1 kilohm	
R2-25	Resistor WS-2-1-1000-II	1 kilohm	
R2-26	Resistor WS-2-1-1000-II	1 kilohm	
R2-27	Resistor WS-1-1-18000-II	18 kilohms	

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R2-28	Resistor WS-0.25-1-10000-II	10 kilohms
R2-29	Resistor WS-0.25-1-1000-II	1 kilohm
R2-30	Resistor WS-0.25-1-51-II	51 ohms
R2-31	Resistor WS-0.25-1-51-II	51 ohms
R2-32	Resistor WS-0.5-1-0.22-II	0.22 megohm
R2-33	Resistor PEW-20-510 ohms-II	510 ohms
R2-34	Resistor PEW-25x390 ohms-II	390 ohms
R2-35	Resistor WS-0.5-1-27000-II	27 kilohms
R2-36	Resistor PEW-20-5.1 kilohms-II	5.1 kilohms
R2-37	Resistor WS-2-1-56000-II	56 kilohms
R2-38	Resistor WS-2-1-56000-II	56 kilohms
R2-39	Resistor WS-2-1-24000-II	24 kilohms
C2-1	Capacitor KSO-2-500-B-100-II	100 pF
C2-2	Capacitor KSO-2-500-B-1000-II	1000 pF
C2-3	Capacitor KSO-2-500-B-1000-II	1000 pF
C2-4	Capacitor KSO-2-500-B-1000-II	1000 pF
C2-5	Capacitor KSO-2-500-B-100-II	100 pF
C2-6	Capacitor KSO-2-500-B-1000-II	1000 pF
C2-7	Capacitor KTK-1-M-10-II	10 pF
C2-8	Capacitor KBG-I-200-0.1-II	0.1 µF
C2-9	Capacitor KBG-MN-A-400-2-III	2 µF
C2-10	Capacitor KBG-1-600-0.01-II	0.01 µF
C2-11	Capacitor KSO-2-500-B-1000-II	1000 pF
C2-12	Capacitor KBG-MP-N-600-1.0-III	1 µF
C2-13	Capacitor KBG-MP-2N-400-0.25-II	0.25 µF
C2-14	Capacitor KBG-MN-N-400-0.25-II	0.25 µF
C2-15	Capacitor KBG-MP-2N-400-0.25-II	0.25 µF
C2-16	Capacitor KBG-1-400-0.05-II	0.05 µF
C2-17	Capacitor KBG-1-600-0.01-II	0.01 µF
C2-19 C2-20	Capacitor KBG-MN-2A-400-2x2.0-II	2x2.0 µF
C2-21 C2-22	Capacitor KBG-MN-2A-400-2x2.0-II	2x2.0 µF
L2-1	Induction coil	2.9 µH
L2-2	Induction coil	2.4 µH
L2-3	Choke	90 µH
L2-4	Choke	200 µH
D12-1	Low frequency choke 4 H ± 10%	4 H
Tr2-1	Transformer	110 V/200 V/ 5 V/5 V/6.3V
Tr2-2	Transformer	110 V/350 V/ 350 V
Zw2-1	High-frequency connector	
Zw2-2	High-frequency connector	
Zw2-3	High-frequency connector	
Zw2-4	Krife-type connector	10-contact
G2-1	Jack	
B2-1	Fuse	2 A
B2-2	Fuse	1 A
W2-1	Double-pole switch	
W2-2	Double-pole switch	
V2-1	Valve 6Z4	
V2-2	Valve 6H6S	
V2-3	Valve 6Z4	
V2-4	Valve 6Z4	
V2-5	Valve 6P3S	
V2-7	Valve 5C4S	
V2-8	Valve 5C4S	
V2-9	Valve 5C4S	
V2-10	Valve SG3S	
V2-11	Neon lamp MN-3	
V2-12	Neon lamp MN-3	

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Range Measuring System

Range unit

R8-1	Resistor WS-0.5-1-2.2-II	2.2 megohms	
R8-2	Resistor WS-0.25-1-510-II	510 ohms	
R8-3	Resistor WS-1-1-0.1-II	0.1 megohm	
R8-4	Resistor WS-1-1-47000-II	47 kilohms	
R8-5A	Resistor WS-2-1-22000-II	22 kilohms	
R8-5B	Resistor WS-2-1-22000-II	22 kilohms	
R8-6	Resistor WS-0.5-1-22000-II	22 kilohms	
R8-7	Resistor WS-1-1-0.13-I	0.13 megohm	
R8-8	Resistor WS-1-1-51000-II	51 kilohms	
R8-9A	Resistor WS-2-1-22000-II	22 kilohms	
R8-9B	Resistor WS-2-1-22000-II	22 kilohms	
R8-10	Resistor WS-2-1-0.27-I	0.27 megohms	
R8-11	Resistor WS-0.25-1-62000-II	62 kilohms	
R8-12	Resistor SP-II-2a-47A	47 kilohms	
R8-13A	Resistor WS-2-1-22000-II	22 kilohms	
R8-13B	Resistor WS-2-1-22000-II	22 kilohms	
R8-14	Resistor WS-2-1-0.27-I	0.27 megohm	
R8-15	Resistor WS-0.25-1-24000-I	24 kilohms	
R8-16	Resistor SP-II-2a-47A	47 kilohms	
R8-17	Resistor WS-1-1-51000-I	51 kilohms	
R8-18	Resistor WS-2-1-0.1-II	0.1 megohm	
R8-19	Resistor SP-II-2a-470A	470 kilohms	
R8-20	Resistor WS-2-1-1000-I	1 kilohm	
R8-21	Resistor SP-II-2a-470A	470 kilohms	
R8-22	Resistor WS-0.25-1-0.51-I	0.51 megohm	
R8-23	Resistor WS-1-1-0.1-II	0.1 megohm	
R8-24	Resistor WS-1-1-10000-II	10 kilohms	
R8-25	Resistor WS-2-1-10000-II	10 kilohms	
R8-26	Resistor WS-1-1-1.0-II	1 megohm	
R8-27	Resistor SP-II-2a-68A	68 kilohms	
R8-28	Resistor WS-1-1-0.82-II	0.82 megohm	
R8-29	Resistor WS-0.25-1-27000-I	27 kilohms	
R8-30	Resistor WS-2-1-5100-I	5.1 kilohms	
R8-31	Resistor WS-2-1-5100-I	5.1 kilohms	
R8-32A	Resistor WS-2-1-10000-II	10 kilohms	
R8-32B	Resistor WS-2-1-10000-II	10 kilohms	
R8-33	Resistor WS-2-1-4700-II	4.7 kilohms	
R8-34	Resistor WS-2-1-3.3-II	3.3 megohms	
R8-35	Resistor WS-2-1-5600-II	5.6 kilohms	
R8-36	Resistor SP-II-2a-470 A	470 kilohms	
R8-37	Resistor WS-0.25-1-27000-I	27 kilohms	
R8-38	Resistor SP-II-2a-470A	470 kilohms	
R8-39	Resistor WS-2-1-0.1-I	0.1 megohm	
R8-40	Resistor WS-2-1-0.1-I	0.1 megohm	
R8-41	Resistor WS-2-1-10000-II	10 kilohms	
R8-42A	Resistor WS-2-1-3900-II	3.9 kilohms	
R8-42B	Resistor WS-2-1-3900-II	3.9 kilohms	
R8-43	Resistor WS-0.25-1-0.47-I	0.47 megohm	
R8-44	Resistor WS-0.25-1(75000-0.15)-II	75 kilohms-0.15 megohm	Used when tuning, in stations in current production.
R8-45A	Resistor WS-2-1-47000-I	47 kilohms	
R8-45B	Resistor WS-2-1-47000-I	47 kilohms	

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R8-96	Resistor WS-0.5-1-2.0-II	2.0 megohms	
R8-97A	Resistor WS-2-1-22000-I	22 kilohms	
R8-97B	Resistor WS-2-1-22000-I	22 kilohms	
C8-1	Capacitor KSO-6-1000-G-560-I	560 pF	
C8-2	Capacitor KSO-2-500-W-510-I	510 pF	
C8-3	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-4	Capacitor KTK-1-M-20-I	20 pF	
C8-5	Capacitor KSO-2-500-W-510-I	510 pF	
C8-6	Capacitor KTK-5-25/150	25/150 pF	
C8-7	Capacitor KTK-2-D-100-II	100 pF	
C8-8	Capacitor KTK-1-M-5-II	5 pF	
C8-9	Capacitor KSO-5-500-B-1800-I	1800 pF	
C8-10	Capacitor KSO-5-500-B-1500-I	1500 pF	
C8-11	Capacitor KSO-5-500-B-3900-II	3900 pF	
C8-12	Capacitor KTK-1-M-5-II	5 pF	
C8-13	Capacitor KSO-5-500-B-3900-II	3900 pF	
C8-14	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-15	Capacitor KSO-5-500-B-2000-I	2000 pF	
C8-16	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-17	Capacitor KBG-MP-2W-1000-0.1-II	0.1 µF	
C8-18	Capacitor KBG-MN-3A-600-2x0.1-II	1.0 µF	In one case with C8-49
C8-19	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-20	Capacitor KSO-2-500-W-510-I	510 pF	
C8-21	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-22	Capacitor KTK-1-M-20-I	20 pF	
C8-23	Capacitor KSO-2-500-B-300-I	300 pF	
C8-24	Capacitor KBG-MP-2N-1000-0.1-II	0.1 µF	
C8-25	Capacitor KTK-2-D-100-II	100 pF	
C8-26	Capacitor KBG-I-600-0.01-II	0.01 µF	
C8-27	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-28	Capacitor KSO-6-1000-G-220-I	220 pF	
C8-29	Capacitor KTK-2-D-100-II	100 pF	
C8-30	Capacitor KSO-5-500-G-1000-I	1000 pF	
C8-31	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-32	Capacitor KBG-MN-3A-600-2x1.0-II	1.0 µF	In one case
C8-33	Capacitor KBG-MN-3A-600-2x1.0-II	1.0 µF	
C8-34	Capacitor KBG-MP-ZW-1000-0.1-II	0.1 µF	
C8-35	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-36	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-37	Capacitor KTK-2-M-75-I	75 pF	
C8-38	Capacitor KTK-3-M-150-I	150 pF	
C8-39	Capacitor KTK-2-D-100-II	100 pF	
C8-41	Capacitor KSO-2-500-W-620-I	620 pF	
C8-42	Capacitor KBG-MP-2N-1000-0.1-II	0.1 µF	
C8-43	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-44	Capacitor KSO-2-500-B-300-I	300 pF	
C8-45	Capacitor KTK-1-M-20-I	20 pF	
C8-46	Capacitor KBG-MP-2W-1000-0.1-II	0.1 µF	
C8-47	Capacitor KTK-2-M-51-I	51 pF	
C8-48	Capacitor KTK-2-M-51-I	51 pF	
C8-49	Capacitor KBG-MN-3A-600-2x0.1-II	1.0 µF	In one case with C8-18
C8-50	Capacitor KBG-MP-2W-600-0.5-II	0.5 µF	
C8-51	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-52	Capacitor KBG-MN-3A-600-2x0.5-II	0.5 µF	In one case with C8-68
C8-53	Capacitor KBG-MP-2W-600-0.25-II	0.25 µF	
C8-54	Capacitor KPK-5-25/150	25/150 pF	
C8-55	Capacitor KSO-5-500-G-2700-I	2700 pF	
C8-56	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C8-57	Capacitor KTK-4-M-200-I	200 pF	
C8-58	Capacitor KPK-5-25/150	25/150 pF	

C8-59	Capacitor KTK-4-M-200-I	200 pF	
C8-60	Capacitor KSO-6-1000-G-2000-I	2000 pF	
C8-61	Capacitor KSO-6-1000-G-2000-I	2000 pF	
C8-62	Capacitor KSO-2-500-G-1000-I	1000 pF	
C8-63	Capacitor KSO-2-500-G-1000-I	1000 pF	
C8-64	Capacitor KSO-6-1000-G-2700-I	2700 pF	
C8-65	Capacitor KPK-5-25/75	25/75 pF	
C8-66	Capacitor KSO-5-500-B-2000-I	2000 pF	
C8-67	Capacitor KSO-2-500-B-200-II	200 pF	
C8-68	Capacitor KBG-MN-3A-600-2x0.5-II	0.5 µF	In one case with C8-52
C8-69	Capacitor KTK-3-M-130-I	130 pF	
C8-70	Capacitor KTK-3-M-150-I	150 pF	
C8-71	Capacitor KTK-1-D-51-I	51 pF	
C8-72	Capacitor KTK-3-M-150-I	150 pF	
C8-73	Capacitor KTK-1-D-51-I	51 pF	
C8-74	Capacitor KSO-5-500-B-1500-I	1500 pF	
C8-76	Capacitor KDK-1-D-24-II	24 pF	
C8-77A	Capacitor KTK-5-S-100-I	100 pF	
C8-77B	Capacitor KTK-5-S-100-I	100 pF	
C8-77C	Capacitor KTK-5-S-100-I	100 pF	
C8-77D	Capacitor KTK-5-S-100-I	100 pF	
C8-77E	Capacitor KTK-5-S-100-I	100 pF	
C8-77F	Capacitor KTK-5-S-100-I	100 pF	
C8-77G	Capacitor KTK-5-S-100-I	100 pF	
C8-77H	Capacitor KTK-5-S-100-I	100 pF	
C8-77I	Capacitor KTK-5-S-100-I	100 pF	
C8-79	Capacitor KTK-1-M-22-II	22 pF	
L8-1	Choke	9 MH	
L8-2	Induction coil	10 MH	
L8-3	Induction coil	10 MH	
L8-4	Induction coil	500 MH	
L8-5	Induction coil	500 MH	
V8-1	High-frequency pentode 6K3		
V8-2	Double triode 6N9S		
V8-3	Double triode 6N9S		
V8-4	Double triode 6N9S		
V8-5	Beam tetrode 6P3S		
V8-6	Double triode 6N8S		
V8-7	Double triode 6N8S		
V8-8	Double triode 6N8S		
V8-9	High-frequency pentode 6Z4		
V8-10	High-frequency pentode 6Z4		
V8-11	Double diode 6H6S		
V8-12	High-frequency pentode 6Z4		
V8-13	Pentode 6P9		
V8-14	Double triode 6N8S		
V8-15	Double triode 6N8S		
V8-16	Double triode 6N8S		
V8-17	Pentode 6P9		
Tr8-1	Phase-shifting transformer		
Tr8-2	Phase-shifting transformer		
Tr8-3	Transformer		
Tr8-4	Transformer		
Kw8-1	Crystal	74.955 kc/s	
Kw8-2	Crystal	74.955 kc/s	
G8-1	Telephone jack		
G8-2	Telephone jack		
G8-3	Telephone jack		
G8-4	Telephone jack		
G8-5	Telephone jack		
G8-6	Telephone jack		
G8-7	Telephone jack		

G8-8	Telephone jack		
G8-9	Telephone jack		
G8-10	Telephone jack		
G8-11	Telephone jack		
G8-12	Telephone jack		
G8-13	Telephone jack		
G8-14	Telephone jack		
G8-15	Telephone jack		
Zw8-1	Knife-type connector	10-contact	
Zw8-2	Knife-type connector	16-contact	
Zw8-3	High-frequency connector	1-point	
Zw8-4	High-frequency connector	1-point	
Zw8-5	High-frequency connector	1-point	
Zw8-6	Connector	1-point	

Range and very-narrow gate indicator unit

R3-1	Resistor WS-0.25-1-22000-II	22 kilohms	
R3-2	Resistor WS-0.25-1-0.22-II	0.22 megohm	
R3-3	Resistor WS-0.25-1-100-II	100 ohms	
R3-5	Resistor WS-0.5-1-100-II	100 ohms	
R3-6	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-7	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-8	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-9	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-10	Resistor WS-0.25-1-0.22-II	0.22 megohm	
R3-11	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-12	Resistor WS-0.25-1-0.22-II	0.22 megohm	
R3-13	Resistor SP-1-2a-150 A 13 1	150 kilohms	
R3-14	Resistor SP-1-2a-150 A 13 1	150 kilohms	
R3-15	Resistor WS-2-1-0.1-II	0.1 megohm	
R3-16	Resistor SP-1-2a-330 A 13 1	330 kilohms	
R3-17	Resistor SP-1-2a-330 A 13 1	330 kilohms	
R3-18	Resistor WS-2-1-47000-II	47 kilohms	
R3-19	Resistor WS-2-1-0.15-II	0.15 megohm	
R3-20	Resistor WS-2-1-0.1-II	0.1 megohm	
R3-21	Resistor WS-2-1-0.1-II	0.1 megohm	
R3-22	Resistor WS-2-1-68000-II	68 kilohms	
R3-23	Resistor WS-1-1-0.1-II	0.1 megohm	
R3-24	Resistor WS-0.25-1-0.22-II	0.22 megohm	
R3-25	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-26	Resistor SP-II-2a-1000 A	1 megohm	
R3-27	Resistor SP-II-2a-1000 A	1 megohm	
R3-28	Resistor WS-2-1-0.12-II	0.12 megohm	
R3-29	Resistor WS-2-1-0.15-II	0.15 megohm	
R3-30	Resistor WS-2-1-0.15-II	0.15 megohm	
R3-31	Resistor SP-II-2a-1000 A	1 megohm	
R3-32	Resistor SP-II-2a-1000 A	1 megohm	
R3-33	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-34	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-35	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-36	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-37	Resistor WS-0.25-1-1000-I	1 kilohm	
R3-38	Resistor WS-2-1-5100-I	5.1 kilohms	
R3-39	Resistor WS-1-1-10000-II	10 kilohms	
R3-40	Resistor WS-2-1-5100-I	5.1 kilohms	
R3-41	Resistor WS-2-1-5100-I	5.1 kilohms	
R3-42	Resistor WS-0.25-1-0.47-II	0.47 megohm	
R3-43	Resistor WS-2-1-1000-II	1 kilohm	
R3-44	Resistor WS-0.25-1-33000-II	33 kilohms	
R3-45	Resistor WS-0.25-1-4700-II	4.7 kilohms	
R3-46	Resistor WS-1-1-15000-II	15 kilohms	
R3-47	Resistor WS-1-1-10000-II	10 kilohms	

R3-48	Resistor WS-2-1-0.1-II	0.1 megohm	
R3-49	Resistor WS-2-1-0.1-II	0.1 megohm	
R3-50	Resistor WS-0.25-1-22000-II	22 kilohms	
R3-51	Resistor WS-0.25-1-82-II	82 ohms	
R3-52	Resistor WS-2-1-10000-II	10 kilohms	
R3-53	Resistor WS-0.5-1-100-II	100 ohms	
R3-54	Resistor WS-0.5-1-160-II	160 ohms	
R3-55	Resistor WS-0.25-1-200-II	200 ohms	
R3-56	Resistor WS-0.25-1-22000-II	22 kilohms	
R3-57	Resistor WS-2-1-10000-II	10 kilohms	
R3-58	Resistor WS-0.5-1-160-II	160 ohms	
C3-1	Capacitor KSO-5-500-G-2700-II	2700 pF	
C3-2	Capacitor KTK-3-M-130-I	130 pF	
C3-3	Capacitor KSO-5-500-G-2700-II	2700 pF	
C3-4	Capacitor KSO-5-500-G-2700-II	2700 pF	
C3-5	Capacitor KTK-3-M-130-I	130 pF	
C3-6	Capacitor KSO-5-500-G-2700-II	2700 pF	
C3-7	Capacitor KSO-10-3000-B-1000-II	1000 pF	
C3-8	Capacitor KSO-10-3000-B-1000-II	1000 pF	
C3-9	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF	In one
C3-10	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF	case
C3-11	Capacitor KBG-MP-2W-1000-0.1-II	0.1 µF	
C3-12	Capacitor KSO-10-2000-B-10000-II	10000 pF	
C3-13	Capacitor KSO-10-3000-B-1000-II	1000 pF	
C3-14	Capacitor KSO-5-500-G-2700-II	2700 pF	
C3-15	Capacitor KSO-5-500-G-5100-I	5100 pF	
C3-16	Capacitor KSO-5-500-G-2700-II	2700 pF	
C3-17	Capacitor KSO-5-500-G-2700-II	2700 pF	
C3-18	Capacitor KSO-5-500-G-5100-I	5100 pF	
C3-19	Capacitor KSO-5-500-G-2700-II	2700 pF	
C3-20	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C3-21	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C3-22	Capacitor KSO-2-500-B-1000-II	1000 pF	
C3-23	Capacitor KBG-MP-3N-600-2x0.1-II	0.1 µF	In one
C3-24	Capacitor KBG-MP-3N-600-2x0.1-II	0.1 µF	case
C3-25	Capacitor KBG-I-600-0.01-II	0.01 µF	
C3-26	Capacitor KTK-2-D-240-II	240 pF	
C3-27	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C3-28	Capacitor KBG-MP-2N-600-1.0-II	1.0 µF	
C3-29	Capacitor KSO-8-1000-B-10000-II	10000 pF	
C3-30	Capacitor KSO-5-500-B-2000-II	2000 pF	
C3-31	Capacitor KTK-2-D-300-I	300 pF	
C3-32	Capacitor KSO-5-500-G-2700-II	2700 pF	
C3-33	Capacitor KSO-2-500-B-300-I	300 pF	
C3-34	Capacitor KSO-2-500-B-300-I	300 pF	
C3-35	Capacitor KSO-2-500-B-300-I	300 pF	
C3-36	Capacitor KSO-2-500-B-300-I	300 pF	
C3-37	Capacitor KSO-2-500-B-300-I	300 pF	
C3-38	Capacitor KSO-2-500-B-300-I	300 pF	
C3-39	Capacitor KSO-2-500-B-300-I	300 pF	
C3-40	Capacitor KSO-2-500-B-300-I	300 pF	
C3-41	Capacitor KSO-5-500-B-2700-II	2700 pF	
C3-42	Capacitor KSO-5-500-B-2700-II	2700 pF	
C3-43	Capacitor KBG-MP-2N-600-1.0-II	1.0 µF	
C3-44	Capacitor KPK-1-6/25	6/25 pF	
C3-45	Capacitor KPK-1-6/25	6/25 pF	
C3-46	Capacitor KTK-1-D-51-I	51 pF	
C3-47	Capacitor KTK-1-D-51-I	51 pF	
C3-48A	Capacitor KSO-2-500-B-300-I	300 pF	
C3-48B	Capacitor KSO-2-500-B-300-I	300 pF	
C3-48C	Capacitor KSO-2-500-B-300-I	300 pF	
C3-49	Capacitor KBG-MP-2W-600-0.5-II	0.5 µF	
C3-50	Capacitor KSO-5-500-B-2700-II	2700 pF	
C3-51	Capacitor KTK-2-D-300-I	300 pF	

E3-1	Delay line	0.15 µ sec.
E3-2	Delay line	0.4 µ sec.
L3-1	Choke	85 MH
L3-2	Choke	1 MH
L3-3	Induction coil	23 MH
L3-4	Induction coil	23 MH
L3-5	Induction coil	3.6 MH
L3-6	Induction coil	3.6 MH
L3-7	Induction coil	3.6 MH
L3-8	Induction coil	3.6 MH
L3-9	Induction coil	3.6 MH
L3-10	Induction coil	3.6 MH
L3-11	Induction coil	3.6 MH
L3-12	Induction coil	3.6 MH
L3-13	Induction coil	1.7 MH
L3-14	Induction coil	1.7 MH
L3-15A	Induction coil	3.6 MH
L3-15B	Induction coil	3.6 MH
L3-15C	Induction coil	3.6 MH
V3-1	Double triode 6N8S	
V3-2	High-frequency pentode 6Z4	
V3-3	Double triode 6N8S	
V3-4	Double triode 6N8S	
V3-5	Double triode 6N8S	
V3-6	Cathode-ray tube 8LO30	
V3-7	Cathode-ray tube 8LO30	
Z3-8	Filament lamp, type 14	
Z3-9	Filament lamp, type 14	
Tr3-1	Transformer	6.3V/6.3V; 2.1A/1.5A; 427 c/s
Tr3-2	Transformer	75 kc/s
Tr3-3	Transformer	75 kc/s
Tr3-4	Transformer	3.75 kc/s
Tr3-5	Transformer	3.75 kc/s
Tr3-6	Blocking oscillator transformer	
Tr3-7	Blocking oscillator transformer	
Tr3-8	Blocking oscillator transformer	
W3-1	Double-pole switch	
W3-2	Double-pole switch	
G3-1	Telephone jack	
G3-2	Telephone jack	
G3-3	Telephone jack	
G3-4	Telephone jack	
Zw3-1	Knife-type connector	10-contact
Zw3-2	Knife-type connector	10-contact
Zw3-3	Connector	1-point
Zw3-4	High-frequency connector	1-point
Zw3-5	High-frequency connector	1-point
Zw3-6	High-frequency connector	1-point
Zw3-7	High-frequency connector	1-contact
Zw3-8	Connector	1-point

Range unit

R4-1	Resistor WS-0.25-1-0.1-I	0.1 megohm
R4-2	Resistor WS-1-1-0.15-I	0.15 megohm
R4-3	Resistor WS-0,5-1-3900-II	3.9 kilohms
R4-4	Resistor WS-0.25-1-0.47-I	0.47 megohm
R4-5	Resistor WS-0.5-1-1000-II	1 kilohm
R4-6	Resistor WS-1-1-3900-II	3.9 kilohms
R4-7	Potentiometer 1000 ohms ± 10%, 3 W	1 kilohm
R4-8	Resistor WS-1-1-3900-II	3.9 kilohms

R4-9	Resistor, wire-wound, 1600 ohms ± 10%, 1 W	1.6 kilohms	
R4-10	Potentiometer, wire-wound, 1000 ohms ± 10%, 3 W	1 kilohm	
R4-11	Potentiometer, wire-wound, 1000 ohms ± 10%, 3 W	1 kilohm	
R4-12	Resistor, wire-wound, 1600 ohms ± 10%, 1 W	1.6 kilohms	
R4-13	Resistor WS-2-1-6800-II	6.8 kilohms	
R4-14	Resistor WS-2-1-6800-II	6.8 kilohms	
R4-15	Resistor WS-2-1-6800-II	6.8 kilohms	
R4-16	Resistor WS-1-1-47000-II	47 kilohms	
R4-17	Resistor WS-0.5-1-1.0-II	1 megohm	
R4-18	Resistor WS-0.25-1-150-II	150 ohms	
R4-19	Resistor WS-2-1-1000-II	1 kilohm	
R4-20	Resistor SP-II-2b-10 A	10 kilohms	
R4-21	Decade potentiometer DP-10000	10 kilohms	
R4-22	Resistor WS-2-1-3600-II	3.6 kilohms	
R4-23	Resistor SP-II-2a-1 A	1 kilohm	
R4-24A	Resistor PO-10-5000-I	5 kilohms	
R4-24B	Resistor PO-10-5000-I	5 kilohms	
R4-25	Resistor SP-II-2a-2.2 A	2.2 kilohms	
R4-26	Resistor WS-2-1-1000-II	1 kilohm	
R4-27	Resistor WS-2-1-2200-II	2.2 kilohms	
C4-1	Capacitor KSO-2-500-A-1000-II	1000 pF	
C4-2	Capacitor KSO-2-500-A-1000-II	1000 pF	
C4-3	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF	In one case with C4-16
C4-4	Capacitor KSO-8-1000-A-10000-II	10000 pF	
C4-5	Capacitor KTK-2-M-51-II	51 pF	
C4-6	Capacitor KSO-2-500-A-1000-II	1000 pF	
C4-7	Capacitor KPK-5-25/150	25/150 pF	
C4-8	Capacitor KSO-2-500-A-1000-II	1000 pF	
C4-9	Capacitor KBG-MP-2W-600-0.5-II	0.5 µF	
C4-10	Capacitor KBG-I-600-0.025-II	0.025 µF	
C4-11	Capacitor KBG-I-400-0.05-II	0.05 µF	
C4-14	Capacitor KBG-MN-2A-400-4.0-II	4.0 µF	
C4-15	Phase shifter		
C4-16	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF	In one case with C4-3
C4-17	Capacitor KBG-MP-2W-600-0.5-II	0.5 µF	
V4-1	Double triode 6N8S		
V4-2	High-frequency pentode 6Z4		
V4-3	Dial lamp MN-15		
Tr4-1	Transformer		
W4-3	Double-pole switch		
W4-4	Double-pole switch		
W4-5	Control button	Single pole	
W4-6	Start button		
M4-2	Motor 2ASM-200	110 V;6.2 W	
M4-3	Selsyn DI-511, class I	110 V;50 c 0.2 A	
M4-4	Selsyn DI-511, class II	110 V;50 c 0.2 A	
G4-1	Telephone jack		
G4-6	Telephone jack		
Zw4-1	High-frequency connector	1-point	
Zw4-2	High-frequency connector	1-point	
Zw4-3	Knife-type connector	16-contact	
Zw4-4	Knife-type connector	16-contact	

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SECRET

Automatic range finder unit

R7-1	Resistor WS-0.5-1-68-II	68 ohms
R7-2	Resistor WS-0.25-1-100-II	100 ohms
R7-3	Resistor WS-1-1-0.27-II	0.27 megohm
R7-4	Resistor WS-0.5-1-30000-I	30 kilohms
R7-5	Resistor WS-0.5-1-0.1-II	0.1 megohm
R7-6	Resistor WS-0.5-1-10000-II	10 kilohms
R7-7	Resistor WS-0.25-1-150-II	150 ohms
R7-8	Resistor WS-0.25-1-100-II	100 ohms
R7-9	Resistor WS-1-1-0.27-II	0.27 megohm
R7-10	Resistor WS-0.5-1-30000-I	30 kilohms
R7-11	Resistor WS-0.5-1-0.1-II	0.1 megohm
R7-12	Resistor WS-0.5-1-10000-II	10 kilohms
R7-13	Resistor WS-0.5-1-2400-II	2.4 kilohms
R7-14	Resistor WS-2-1-47000-II	47 kilohms
R7-15	Resistor WS-2-1-47000-II	47 kilohms
R7-16	Resistor WS-2-1-47000-II	47 kilohms
R7-17	Resistor SP-II-2a-3.3 A	3.3 kilohms
R7-18	Resistor WS-2-1-510-II	510 ohms
R7-19	Resistor, tubular, I-5000	5 kilohms
R7-20	Resistor, tubular, I-5000	5 kilohms
R7-21	Resistor WS-2-1-47000-II	47 kilohms
R7-22	Resistor WS-2-1-47000-II	47 kilohms
R7-23	Resistor WS-2-1-47000-II	47 kilohms
R7-24	Resistor WS-0.5-1-2400-I	2.4 kilohms
R7-25	Resistor WS-2-1-2000-I	2 kilohms
R7-26	Resistor WS-0.5-1-0.2-I	0.2 megohm
R7-27	Resistor WS-0.5-1-100-II	100 ohms
R7-28	Resistor WS-2-1-8200-II	8.2 kilohms
R7-29	Resistor WS-2-1-8200-II	8.2 kilohms
R7-30	Resistor WS-0.5-1-100-II	100 ohms
R7-31	Resistor WS-0.5-1-20000-I	20 kilohms
R7-32	Resistor WS-1-1-4700-I	4.7 kilohms
R7-33	Resistor WS-2-1-22000-II	22 kilohms
R7-34	Resistor WS-2-1-22000-II	22 kilohms
R7-35	Resistor WS-1-1-470-II	470 ohms
R7-36	Resistor SP-II-2a-2.2 A	2.2 kilohms
R7-37	Resistor WS-0.5-1-0.2-I	0.2 megohm
R7-38	Resistor WS-2-1-15000-II	15 kilohms
R7-39	Resistor WS-2-1-15000-II	15 kilohms
R7-40	Resistor WS-2-1-1000-II	1 kilohm
R7-41	Resistor WS-2-1-1000-II	1 kilohm
R7-42	Resistor WS-2-1-1000-II	1 kilohm
R7-43	Resistor WS-2-1-1000-II	1 kilohm
R7-44	Resistor WS-0.5-1-0.51-I	0.51 megohm
R7-45	Resistor WS-0.5-1-0.91-I	0.91 megohm
R7-46	Resistor WS-0.5-1-18000-II	18 kilohms
R7-47	Resistor WS-0.5-1-0.91-I	0.91 megohm
R7-48	Resistor WS-0.5-1-10000-II	10 kilohms
R7-49	Resistor WS-1-1-0.1-II	0.1 megohm
R7-50	Resistor WS-1-1-0.15-II	0.15 megohm
R7-51	Resistor WS-1-1-0.1-II	0.1 megohm
R7-52	Resistor WS-0.5-1-0.2-I	0.2 megohm
R7-53	Resistor WS-1-1-1000-II	1 kilohm
R7-54	Resistor WS-0.5-1-82000-II	82 kilohms
R7-55	Resistor WS-0.5-1-1000-II	1 kilohm
R7-56	Resistor SP-II-2a-100 A	100 kilohms
R7-57	Resistor WS-0.5-1-30000-I	30 kilohms
R7-58	Resistor PEW-20-3 kilohms-I	3 kilohms
R7-59	Resistor WS-2-1-20000-I	20 kilohms
R7-60	Resistor WS-2-1-20000-I	20 kilohms
R7-61	Resistor WS-0.5-1-10000-II	10 kilohms

R7-62	Resistor WS-0.5-1-10000-II	10 kilohms	
R7-63	Resistor SP-II-2a-2200 A	2.2 megohms	
R7-64	Resistor WS-0.5-1-2.0-I	2 megohms	
R7-65	Resistor WS-0.5-1-56000-II	56 kilohms	
R7-66	Resistor WS-0.5-1-1000-II	1 kilohm	
R7-67	Resistor WS-0.5-1-510-II	510 ohms	
R7-68	Resistor WS-0.5-1-30000-I	30 kilohms	
R7-69	Resistor WS-0.5-1-510-II	510 ohms	
R7-70	Resistor WS-0.5-1-1000-II	1 kilohm	
R7-71	Resistor WS-0.5-1-82000-II	82 kilohms	
R7-72	Resistor WS-0.5-1-82000-II	82 kilohms	
R7-73	Resistor WS-0.5-1-1.2-II	1.2 megohm	
R7-74	Resistor WS-0.5-1-0.1-II	0.1 megohm	
R7-75	Resistor WS-2-1-82000-II	82 kilohms	
R7-76	Resistor WS-2-1-82000-II	82 kilohms	
R7-77	Resistor WS-0.5-1-1000-II	1 kilohm	
R7-78	Resistor WS-0.5-1-1000-II	1 kilohm	
R7-79	Resistor WS-0.5-1-0.1-II	0.1 megohm	
R7-80	Resistor SP-II-2a-100 A	100 kilohms	
R7-81	Resistor WS-0.5-1-0.1-II	0.1 megohm	
R7-82	Resistor WS-0.5-1-1.2-II	1.2 megohm	
R7-83	Resistor WS-0.5-1-0.1-II	0.1 megohm	
R7-84	Resistor WS-0.5-1-39000-II	39 kilohms	
R7-85	Resistor WS-0.5-1-75000-I	75 kilohms	
R7-86	Resistor SP-II-2a-47 A	47 kilohms	
R7-87	Resistor WS-0.5-1-1.2-II	1.2 kilohm	
R7-88	Resistor WS-0.5-1-0.43-I	0.43 megohm	
R7-89	Resistor WS-0.5-1-3000-I	3 kilohms	
R7-90	Resistor WS-0.5-1-3000-I	3 kilohms	
R7-91	Resistor WS-0.5-1-1.8-II	1.8 megohm	
R7-92	Resistor WS-0.5-1-1.8-II	1.8 megohm	
R7-93	Resistor SP-II-2a-1000 A	1 megohm	
R7-94	Resistor WS-0.5-1-1000-II	1 kilohm	
R7-95	Resistor WS-0.5-1-1.2-II	1.2 megohm	
R7-96	Resistor PEW-20-3 kilohms-I	3 kilohms	
R7-97	Resistor WS-0.5-1-51-II	51 ohms	
R7-98	Resistor WS-0.5-1-51-II	51 ohms	
R7-99	Resistor SP-I-2a-10 A 13 1	10 kilohms	
C7-1	Capacitor KBG-MP-3N-600-2x0.1-II	0.1 µF	In one case with C7-14
C7-2	Capacitor KSO-5-500-W-3000-I	3000 pF	
C7-3	Capacitor KSO-5-500-W-3000-I	3000 pF	
C7-5	Capacitor KSO-2-500-W-510-I	510 pF	
C7-6	Capacitor KSO-2-500-W-510-I	510 pF	
C7-7	Capacitor KSO-2-500-W-510-I	510 pF	
C7-8	Capacitor KSO-2-500-W-510-I	510 pF	
C7-9	Capacitor KSO-2-500-W-510-I	510 pF	
C7-10	Capacitor KSO-2-500-W-510-I	510 pF	
C7-11	Capacitor KSO-2-500-W-510-I	510 pF	
C7-12	Capacitor KSO-2-500-W-510-I	510 pF	
C7-13	Capacitor KSO-2-500-W-510-I	510 pF	
C7-14	Capacitor KBG-MP-3N-600-2x0.1-II	0.1 µF	In one case with C7-1
C7-15	Capacitor KSO-5-500-W-3000-I	3000 pF	
C7-16	Capacitor KSO-5-500-W-3000-I	3000 pF	
C7-18	Capacitor KBG-M1-600-0.1-II	0.1 µF	
C7-19	Capacitor KBG-I-600-0.02-II	0.02 µF	
C7-20	Capacitor KSO-5-500-W-5100-I	5100 µF	
C7-21	Capacitor KBG-MP-2W-1000-0.1-II	0.1 µF	
C7-22	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF	In one case with C7-46
C7-23	Capacitor KBG-MP-3N-600-2x0.1-II	0.1 µF	In one case
C7-24	Capacitor KBG-MP-3N-600-2x0.1-II	0.1 µF	
C7-25	Capacitor KBG-MP-3N-600-0.5-II	0.5 µF	

C7-26	Capacitor KSO-5-500-W-5100-I	5100 µF	
C7-27	Capacitor KBG-MP-2B-600-0.5-II	0.5 µF	
C7-28	Capacitor KBG-MP-2N-600-0.25-II	0.25 µF	
C7-29	Capacitor KBG-MP-2W-600-0.5-II	0.5 µF	
C7-30	Capacitor KBG-I-600-0.01-II	0.01 µF	
C7-31	Capacitor KBG-MN-2A-200-2.0-II	2.0 µF	
C7-32	Capacitor KBG-I-600-0.01-II	0.01 µF	
C7-33	Capacitor KBG-MP-2N-200-0.5-II	0.5 µF	
C7-34	Capacitor KBG-MN-2A-400-1.0-II	1 µF	
C7-35	Capacitor KBG-MN-2A-400-1.0-II	1 µF	
C7-36	Capacitor KBG-MN-3A-400-2x2.0-II	2 µF)	In one
C7-37	Capacitor KBG-MN-3A-400-2x2.0-II	2 µF)	case
C7-38	Capacitor KSO-5-500-W-2000-I	2000 pF	
C7-39	Capacitor KBG-5-500-W-2000-I	2000 pF	
C7-40	Capacitor KSO-5-500-W-5100-I	5100 pF	
C7-41	Capacitor KSO-5-500-W-5100-I	5100 pF	
C7-42	Capacitor KBG-MN-2A-400-1.0-II	1 µF	
C7-43	Capacitor KBG-MP-2W-1000-0.1-II	0.1 µF	
C7-44	Capacitor KBG-I-600-0.02-II	0.02 µF	
C7-45	Capacitor KBG-I-600-0.02-II	0.02 µF	
C7-46	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF	In one case with C7-22
C7-47	Capacitor KBG-I-200-0.02-II	0.02 µF	
L7-1	Circuit	1 MH	
L7-2	Induction coil	8.75 µH	
L7-3	Induction coil	8.75 µH	
L7-4	Induction coil	8.75 µH	
L7-5	Induction coil	8.75 µH	
L7-6	Induction coil	8.75 µH	
L7-7	Induction coil	8.75 µH	
L7-8	Induction coil	8.75 µH	
L7-9	Induction coil	8.75 µH	
L7-10	Induction coil	8.75 µH	
L7-11	Circuit	1 MH	
E7-1	Delay line	0.55 µsec.	
K7-1	Resonance circuit	455 kc/s	
K7-2	Resonance circuit	455 kc/s	
V7-1	Pentode 6P9		
V7-2	Pentode 6P9		
V7-3	Double diode 6N6S		
V7-4	Pentode 6P9		
V7-5	Pentode 6P9		
V7-6	Pentode 6P9		
V7-7	Pentode 6P9		
V7-8	Double triode 6N8S		
V7-9	Beam tetrode 6P3S		
V7-10	Beam tetrode 6P3S		
V7-11	Double triode 6N8S		
V7-12	Voltage stabiliser SG3S		
V7-13	High-frequency pentode 6K3		
V7-14	Double triode 6N8S		
V7-15	Double triode 6N8S		
V7-16	Double triode 6N9S		
V7-17	Double diode 6N6S		
Tr7-1	Transformer	635 V/127 V	
Tr7-2	Transformer	10 V/10 V	
Tr7-3	Transformer	5 V, 5 V/10 V	
Tr7-4	Transformer	110 V/6.3 V; 6.3 V	
Pp7-1	Milliammeter M-61	20 mA	
D7-1 A,B,C,D	Copper-Oxide rectifier WKW-5-3-1		
Q7-1	Copper-oxide bridge		

G7-2	Telephone jack		
G7-3	Telephone jack		
G7-4	Telephone jack		
G7-5	Telephone jack		
G7-6	Telephone jack		
G7-7	Telephone jack		
G7-8	Telephone jack		
G7-9	Telephone jack		
G7-10	Telephone jack		
G7-11	Telephone jack		
Zw7-1	Knife-type connector	10-contact	
Zw7-2	Knife-type connector	10-contact	
Zw7-3	High-frequency connector	1-point	
Zw7-4	High-frequency connector	1-point	
Zw7-5	High-frequency connector	1-point	

Plan Position Indicator System and Power Packs of Range Measuring and Plan Position Indicator Systems

Plan Position Indicator System

R11-1	Resistor WS-0.25-1-0.22-II	0.22 megohms	
R11-2	Resistor WS-2-1-0.1-II	0.1 megohm	
R11-3	Resistor WS-0.25-1-0.22-II	0.22 megohm	
R11-4	Resistor WS-2-1-0.22-II	0.22 megohm	
R11-5	Resistor SP-II-2a-470 A	470 kilohms	
R11-6	Resistor WS-2-1-10000-II	10 kilohms	
R11-7	Resistor WS-0.5-1-4.7-II	4.7 megohms	
R11-8	Resistor WS-2-1-22000-II	22 kilohms	
R11-9	Resistor WS-2-1-10000-II	10 kilohms	
R11-10	Resistor WS-2-1-22000-II	22 kilohms	
R11-11	Resistor PO-10-3000 ± 10%	3 kilohms	
R11-12	Resistor WS-2-1-4.7-II	4.7 megohms	
R11-13	Resistor WS-2-1-10000-II	10 kilohms	
R11-14	Resistor WS-2-1-39000-II	39 kilohms	
R11-15	Resistor WS-2-1-39000-II	39 kilohms	
R11-16	Resistor SP-II-2a-100 A	100 kilohms	
R11-17	Resistor WS-0.25-1-100-II	100 ohms	
R11-18	Resistor WS-0.5-1-1.0-II	1 megohm	
R11-19	Resistor SP-II-2a-470 A	470 kilohms	
R11-20	Resistor WS-0.25-1-100-II	100 ohms	
R11-21	Resistor WS-2-1-0.1-II	0.1 megohm	
R11-22	Resistor WS-0.25-1-2700-II	2.7 kilohms	
R11-23	Resistor SP-II-2a-470 A	470 kilohms	
R11-24	Resistor PO-10-3000 ± 10%	3 kilohms	
R11-25	Resistor PO-10-3000 ± 10%	3 kilohms	
R11-26	Resistor WS-2-1-3900-II	3.9 kilohms	
R11-27	Resistor WS-0.5-1-5.1-II	5.1 megohms	
R11-28	Resistor WS-2-1-0.12-II	0.12 megohm	
R11-29	Resistor SP-II-2a-22 A 13 1	22 kilohms	
R11-30	Resistor WS-2-1-10000-II	10 kilohms	
R11-31	Resistor WS-2-1-10000-II	10 kilohms	
R11-32	Resistor WS-2-1-4.7-II	4.7 megohms	
R11-33	Resistor WS-2-1-12000-II	12 kilohms	
R11-34	Resistor WS-2-1-10000-II	10 kilohms	
R11-35	Resistor SP-I-2a-4.7 A 13 1	4.7 kilohms	
R11-36	Resistor WS-2-1-2200-II	2.2 kilohms	
R11-37	Resistor WS-2-1-16000-II	16 kilohms	
R11-38	Resistor WS-2-1-16000-II	16 kilohms	
R11-39	Resistor WS-2-1-16000-II	16 kilohms	
R11-40	Resistor WS-1-1-1500-II	1.5 kilohm	
R11-41	Resistor WS-0.5-1-1.0-II	1 megohm	
R11-42	Resistor WS-0.25-1-0.18-II	0.18 megohms	

R11-43	Resistor WS-0.5-1-1.0-II	1 megohm	
R11-44	Resistor WS-1-1-1000-II	1 kilohm	
R11-45	Resistor WS-0.25-1-27000-II	27 kilohms	
R11-46	Resistor WS-0.25-1-5100-II	5.1 kilohms	
R11-47	Resistor SP-I-2a-100 A 13 1	100 kilohms	
R11-48	Resistor WS-2-1-3900-II	3.9 kilohms	
R11-49	Resistor WS-2-1-3900-II	3.9 kilohms	
R11-50	Potentiometer 10 kilohms ± 15%, 4 W	10 kilohms	
R11-51	Resistor WS-1-1-6800-II	6.8 kilohms	
R11-52	Potentiometer 30 ohms ± 10%, 25 W	30 ohms	
R11-53	Resistor WS-2-1-0.1-II	0.1 megohm	
R11-54	Resistor WS-0.5-1-0.1-II	0.1 megohm	
R11-55	Resistor WS-0.5-1-1.5-II	1.5 megohm	
R11-56	Resistor WS-0.5-1-0.22-II	0.22 megohm	
R11-57	Resistor WS-0.5-1-1.0-II	1 megohm	
R11-58	Resistor WS-1-1-5600-II	5.6 kilohms	
R11-59	Resistor WS-2-1-20000-I	20 kilohms	Selected when tuning 5.1 to 20 kilohms.
R11-60	Resistor WS-2-1-1200-II	1.2 kilohms	
R11-61	Resistor WS-2-1-1200-II	1.2 kilohms	
R11-62	Resistor WS-0.5-1-47000-II	47 kilohms	
C11-1	Capacitor KSO-2-500-A-1000-II	1000 pF	
C11-2	Capacitor KSO-2-500-A-1000-II	1000 pF	
C11-3	Capacitor KSO-2-500-A-1000-II	1000 pF	
C11-4	Capacitor KTK-1-D-51-I	51 pF	
C11-5	Capacitor KSO-2-500-W-510-I	510 pF	
C11-6	Capacitor KSO-8-1000-A-10000-II	10000 pF	
C11-7	Capacitor KBG-MN-2A-400-2.0-II	2.0 uF	
C11-8	Capacitor KSO-2-500-A-1000-II	1000 pF	
C11-9	Capacitor KSO-8-1000-A-8200-II	8200 pF	
C11-10	Capacitor KBG-MP-2B-1000-0.1-II	0.1 µF	
C11-11	Capacitor KSO-8-1000-A-10000-II	10000 pF	
C11-12	Capacitor KTK-1-D-51-I	51 pF	
C11-13	Capacitor KTK-3-M-130-I	130 pF	
C11-14	Capacitor KBG-MP-2N-1000-0.1-II	0.1 µF	
C11-15	Capacitor KTK-1-D-24-II	24 pF	
C11-16	Capacitor KTK-1-D-51-I	51 pF	
C11-17	Capacitor KSO-8-1000-A-10000-II	10000 pF	
C11-18	Capacitor KSO-5-500-A-5100-I	5100 pF	
C11-19	Capacitor KBG-MP-2B-600-1.0-II	1.0 µF	
C11-20	Capacitor KSO-8-1000-A-10000-II	10000 pF	
C11-21	Capacitor KSO-2-500-A-1000-II	1000 pF	
C11-22	Capacitor KBG-MP-2B-600-1.0-II	1 µF	
C11-23	Capacitor KBG-MP-2B-600-0.5-II	0.5 µF	
C11-24	Capacitor KBG-MN-2A-400-1.0-II	1 µF	
C11-25	Capacitor KBG-1-?- $\frac{450}{10}$ - M	10 µF	
C11-26	Capacitor KBG-I-200-0.02-II	0.02 µF	
C11-27	Capacitor KBG-MP-2B-600-0.5-II	0.5 µF	
C11-28	Capacitor KBG-MP-2B-600-0.5-II	0.5 µF	
L11-1	Focusing coil	7750 ohms ± 10%	
L11-2	Deflecting coil	320 ohms ± 10%	
V11-1	Double triode 6N8S		
V11-2	Double triode 6N8S		
V11-3	Double triode 6N8S		
V11-4	Beam tetrode 6P3S		
V11-5	Double triode 6N8S		
V11-6	Double triode 6N8S		
V11-7	Double triode 6N8S		
V11-8	Double triode 6N8S		
V11-9	Cathode-ray tube 18LM35		

V11-10	Voltage stabiliser SG4S	
V11-11	High-frequency pentode 6Z8	
V11-12	Beam tetrode 6P3S	
Z11-1	Lamp MN-14	6.3 V;0.25 A
Z11-2	Lamp MN-14	6.3 V;0.25 A
Z11-3	Lamp MN-14	6.3 V;0.25 A
Z11-4	Lamp MN-14	6.3 V;0.25 A
M11-1	Selsyn SS-405, class II	
M11-2	Motor 2ASM-50	20 V
G11-1	Telephone jack	
G11-2	Telephone jack	
G11-3	Telephone jack	
G11-4	Telephone jack	
G11-5	Telephone jack	
G11-6	Telephone jack	
G11-7	Telephone jack	
Zw11-1	Knife-type connector	10-contact
Zw11-2	Knife-type connector	16-contact
Zw11-3	High-frequency connector	1-point
Zw11-4	Connector	1-point

Power Pack of Range Measuring and Plan Position Indicator Systems

R5-1	Resistor WS-2-1-39000-II	39 kilohms
R5-2	Resistor WS-2-1-39000-II	39 kilohms
R5-3	Resistor WS-2-1-39000-II	39 kilohms
R5-4	Resistor WS-2-1-39000-II	39 kilohms
R5-5	Resistor WS-2-0.27-I	0.27 megohm
R5-6	Resistor WS-2-0.27-I	0.27 megohm
R5-7	Resistor WS-2-0.27-I	0.27 megohm
R5-8	Resistor WS-2-0.27-I	0.27 megohm
R5-9	Resistor WS-2-0.27-I	0.27 megohm
R5-10	Resistor WS-2-0.27-I	0.27 megohm
R5-11	Resistor WS-2-0.27-I	0.27 megohm
R5-12	Resistor WS-2-0.27-I	0.27 megohm
R5-13	Resistor WS-2-1-0.1-I	0.1 megohm
R5-14	Resistor WS-1-1-0.33-I	0.33 megohm
R5-15	Resistor WS-2-1-0.16-I	0.16 megohm
R5-16	Resistor WS-1-1-10000-I	10 kilohms
R5-17	Resistor WS-1-1-10000-I	10 kilohms
R5-18	Resistor SP-II-2a-47 A	47 kilohms
R5-25	Resistor WS-0.5-1-1500-I	1.5 kilohm
R5-26	Resistor WS-0.5-1-1500-I	1.5 kilohm
R5-27	Resistor WS-0.5-1-1500-I	1.5 kilohm
R5-28	Resistor WS-0.5-1-1500-I	1.5 kilohm
R5-29	Resistor WS-2-1-39000-II	39 kilohms
R5-30	Resistor WS-2-1-0.1-I	0.1 megohm
R5-31	Resistor WS-2-1-39000-II	39 kilohms
R5-32	Resistor WS-2-1-39000-II	39 kilohms
R5-33	Resistor SP-II-2a-47 A	47 kilohms
R5-34	Resistor WS-2-1-39000-II	39 kilohms
R5-35	Resistor WS-2-1-0.12-I	0.12 megohm
R5-36	Resistor WS-1-1-10000-I	10 kilohms
R5-37	Resistor WS-1-1-36000-II	36 kilohms
R5-38	Resistor WS-1-1-36000-II	36 kilohms
R5-39	Resistor WS-1-1-36000-II	36 kilohms
R5-40	Resistor WS-1-1-36000-II	36 kilohms
R5-41	Resistor WS-1-1-36000-II	36 kilohms
R5-42	Resistor WS-1-1-36000-II	36 kilohms
R5-43	Resistor WS-1-1-36000-II	36 kilohms
R5-44	Resistor WS-1-1-36000-II	36 kilohms
R5-45	Resistor WS-1-1-36000-II	36 kilohms
R5-46	Resistor WS-1-1-36000-II	36 kilohms

R5-47	Resistor WS-1-1-36000-II	36 kilohms	
R5-48	Resistor WS-1-1-36000-II	36 kilohms	
R5-50	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-51	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-52	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-53	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-54	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-55	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-56	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-57	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-58	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-59	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-60	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-61	Resistor WS-1-1-0.56-II	0.56 megohm	
R5-62	Resistor PEW-30-3000-II	3 kilohms	
R5-63	Resistor WS-0.5-1-47000-II	47 kilohms	
R5-64	Resistor WS-1-1-1000-II	1 kilohm	
R5-65	Resistor R-102	120 kilohms	Comes with the set Pp5-1
C5-1	Capacitor KBG-P-2-3-0.1-II	0.1 µF	
C5-2	Capacitor KBG-P-2-3-0.1-II	0.1 µF	
C5-3	Capacitor KBG-P-2-3-0.1-II	0.1 µF	
C5-4	Capacitor KBG-MP-2W-600-0.25-II	0.25 µF	
C5-5	Capacitor KBG-MP-2W-600-0.25-II	0.25 µF	
C5-6	Capacitor KBG-MN-2A-1000-2.0-II	2.0 µF	
C5-7	Capacitor KBG-MN-2A-1000-2.0-II	2.0 µF	
C5-8	Capacitor KBG-MP-2W-600-0.25-II	0.25 µF	
C5-10	Capacitor KBG-MP-2W-400-0.25-II	0.25 µF	
C5-11	Capacitor KBG-MP-2W-600-1.0-II	1 µF	
C5-12	Capacitor RL-7.5-0.1 ± 10%	0.1 µF	
C5-13	Capacitor RL-7.5-0.1 ± 10%	0.1 µF	
V5-1	Kenotron 2C2S		
V5-2	Kenotron 5C3S		
V5-3	Kenotron 5C3S		
V5-4	Transmitting pentode GU-50		
V5-5	Transmitting pentode GU-50		
V5-6	Transmitting pentode GU-50		
V5-7	Transmitting pentode GU-50		
V5-8	Pentode 6P9		
V5-9	Voltage stabiliser SG3S		
V5-10	Kenotron W1-0.02/20		
V5-11	Kenotron 5G3S		
V5-12	Neon lamp MN-3		
Tr5-1	Transformer	110/1900/12.6 2.5/6.5/5./ 6.5/6.5/6.3 V 427 c/s	
Tr5-2	Transformer	110/2x480 V; 427 c/s	
Tr5-3	Transformer	110/4600/2.5V; 427 c/s	
D15-1	Choke	1 H.600 mA	
W5-1	Multiple switch PK-2-10	10 A	
W5-2	Double-pole switch		
W5-3	Double-pole switch		
Zw5-1	High-voltage connector	5 kV	
Zw5-2	Connector (socket)	16-contact	
Zw5-3	Connector (plug)	16-contact	
Zw5-4	Connector	5 kV	
Pp5-1	Voltmeter M-52	0 - 600 V	
B5-1	Fuse	10 A	
B5-2	Fuse	6 A	
B5-3	Fuse	6 A	
B5-4	Fuse	2 A	

Power Pack of Range Measuring System

R9-1	Resistor WS-2-1-47000-II	47 kilohms
R9-2	Resistor WS-2-1-47000-II	47 kilohms
R9-3	Resistor WS-2-1-47000-II	47 kilohms
C9-1	Capacitor KBG-MP-2N-600-0.25-II	0.25 µF
C9-2	Capacitor KBG-MN-2A-600-2.0-II	2.0 µF
C9-3	Capacitor KBG-MN-2A-600-1.0-II	1.0 µF
C9-4	Capacitor KBG-MN-2A-600-1.0-II	1.0 µF
C9-5	Capacitor KSO-5-500-B-1000-II	1000 pF
C9-6	Capacitor KSO-5-500-B-1000-II	1000 pF
C9-7	Capacitor KBG-MN-2A-200-4.0-II	4.0 µF
V9-1	Kenotron 5C3S	
V9-2	Kenotron 5C3S	
V9-3	Voltage stabiliser SG3S	
V9-4	Voltage stabiliser SG3S	
V9-5	Kenotron 5C3S	
Z9-1	Filament lamp MN-15	6.3 V;0.28 A
Tr9-1	Transformer	110/2x450/ 6.3/5 V; 427 c/s
Tr9-2	Transformer	110/2x440/5 V; 427 c/s
Tr9-3	Transformer	110/110 V; 50 c/s
Tr9-4	Transformer	110/20 V; 50 c/s
Tr9-5	Transformer	200/20 V; 50 c/s
Dl9-1	Choke	5H. 200 mA
Dl9-2	Choke	1.5 H. 30 mA
Zw9-1	Knife-type connector	16-contact
Zw9-2	Knife-type connector	10-contact
B9-1	Fuse	5 A
B9-2	Fuse	5 A
B9-3	Fuse	5 A
B9-4	Fuse	5 A

Antenna Positioning System

Automatic Tracking Unit

R6-1	Resistor WS-2-1-0.1-I	0.1 megohm
R6-2	Resistor WS-2-1-33000-I	33 kilohms
R6-3	Resistor WS-1-1-0.1-II	0.1 megohm
R6-4	Resistor WS-0.5-1-5600-I	5.6 kilohms
R6-5	Resistor WS-0.25-1-5100-I	5.1 kilohms
R6-6	Resistor SP-II-2a-1000 A	1 kilohm
R6-7	Resistor WS-2-1-36000-I	36 kilohms
R6-8	Resistor SP-III-$\frac{1}{2}$ a- $\frac{220}{220}$ A 13 1	220 kilohms
R6-9	Resistor SP-III-$\frac{1}{2}$ a- $\frac{220}{220}$ A 13 1	220 kilohms
R6-10	Resistor WS-1-1-47000-II	47 kilohms
R6-11	Resistor WS-1-1-47000-II	47 kilohms
R6-12	Potentiometer, wire-wound, 500 ohms ± 10% 3 W	500 ohms
R6-13	Resistor WS-1-1-11000-II	11 kilohms
R6-14	Resistor SP-II-2a-3300 A	33 kilohms
R6-15	Resistor WS-1-1-11000-II	11 kilohms
R6-16	Resistor WS-2-1-51000-I	51 kilohms
R6-17	Resistor WS-2-1-51000-I	51 kilohms
R6-18	Resistor WS-2-1-39000-II	39 kilohms
R6-19	Resistor WS-2-1-39000-II	39 kilohms

R6-20	Resistor WS-2-1-39000-II	39 kilohms	
R6-21	Resistor WS-2-1-39000-II	39 kilohms	
R6-22	Resistor WS-2-1-20000-I	20 kilohms	
R6-23	Resistor WS-2-1-20000-I	20 kilohms	
C6-1	Capacitor KBG-MN-2A-600-2.0-II	2.0 µF	
C6-2	Capacitor KBG-MN-2A-600-4.0-II	4.0 µF	
C6-3	Capacitor KBG-MN-2A-600-4.0-I	4.0 µF	
C6-4	Capacitor KSO-10-2000-B-10000-II	10000 pF	
R6-5	Capacitor BM-S20-600-10 µF ± 10%	10 µF	
R6-6	Capacitor KBG-MN-2A-600-1.0-II	1 µF	
R6-7	Capacitor KBG-MN-2A-600-1.0-II	1 µF	
R6-8	Capacitor KBG-MN-3A-600-2x2.0-II	2 µF	
R6-9	Capacitor KBG-MN-3A-600-2x2.0-II	2 µF	
R6-10	Capacitor BM-S20-600-10 µF-II	10 µF	
V6-1	Kenotron 5C3S		
V6-2	Double diode 6H6S		
V6-3	High-frequency pentode 6K3		
V6-4	Double triode 6N8S		
V6-5	Voltage stabiliser SG3S		
V6-6	Neon lamp MN-3		
Z6-7	Filament lamp MN-15	6.3 V	
Z6-8	Filament lamp MN-15	6.3 V	
Tr6-1	Transformer	110V/810V/ 6.3V/5 V; 427 c/s	
Tr6-2	Transformer	110V/5.5V	
Tr6-3	Transformer	50 c/s	
D16-1	Choke	4 H; 220 mA	
W6-1	Double-pole switch	2 A; 250 V	
Pp6-1	Milliammeter M-61	20 mA	
P6-2	Double-pole relay	110 V; 50 c/s	
M6-1	Selsyn SS-404, class I	110 V; 50 c/s	
M6-2	Selsyn SS-404, class I	110 V; 50 c/s	
B6-1	Fuse	5 A	
B6-2	Fuse	5 A	
G6-1	Telephone jack		
G6-2	Telephone jack		
G6-3	Telephone jack		
G6-4	Telephone jack		
G6-5	Telephone jack		
G6-6	Telephone jack		
G6-7	Telephone jack		
G6-8	Telephone jack		
G6-9	Telephone jack		
Zw6-1	Knife-type connector	16-contact	
Zw6-2	Knife-type connector	16-contact	
Zw6-3	High-frequency knife-type connector	1-point	

Azimuth and Elevation Tracking Unit

R10-1	Resistor WS-0.5-1-1.0-II	1 megohm	
R10-2	Resistor WS-0.5-1-1.0-II	1 megohm	
R10-3	Resistor WS-0.5-1-1.0-II	1 megohm	
R10-4	Resistor WS-0.5-1-1.0-II	1 megohm	
R10-5	Resistor WS-2-1-20000-I	20 kilohms	
R10-6	Resistor WS-2-1-20000-I	20 kilohms	
R10-7	Resistor WS-0.5-1-0.1-I	100 kilohms	
R10-8	Potentiometer, wire-wound, 25 W, 1000 ohms ± 10%	1 kilohm	
R10-9	Resistor WS-0.5-1-0.1-I	100 kilohms	
R10-10	Resistor WS-2-1-13000-I	13 kilohms	
R10-11	Resistor WS-2-1-13000-I	13 kilohms	
R10-12	Resistor SP-II-2a-2.2 A	2.2 kilohms	

R10-13	Resistor PO-30-25 kilohms ± 5%	25 kilohms
R10-14	Resistor SP-IV-$\frac{1}{2}$a-$\frac{2.2}{2.2}$ A	2.2 kilohms
R10-15	Resistor SP-IV-$\frac{1}{2}$a-$\frac{2.2}{2.2}$ A	2.2 kilohms
R10-16	Resistor WS-2-1-2200-I	2.2 kilohms
R10-17	Resistor PO-10-1000 ohms ± 10%	1 kilohm
R10-18	Resistor WS-0.5-1-0.51-I	0.51 megohm
R10-19	Resistor WS-2-1-3600-I	3.6 kilohms
R10-20	Resistor WS-0.5-1-0.1-I	100 kilohms
R10-21	Resistor WS-0.5-1-0.1-I	100 kilohms
R10-22	Resistor WS-2-1-10000-I	10 kilohms
R10-23	Resistor WS-1-1-0.47-I	0.47 megohm
R10-24	Resistor SP-I-2a-470 A 13 1	470 kilohms
R10-25	Resistor WS-0.5-1-100-II	100 ohms
R10-26	Resistor WS-0.5-1-100-II	100 ohms
R10-27	Resistor WS-2-1-10000-I	10 kilohms
R10-28	Resistor WS-2-1-10000-I	10 kilohms
R10-29	Resistor WS-2-1-10000-I	10 kilohms
R10-30	Resistor WS-2-1-10000-I	10 kilohms
R10-31	Resistor WS-1-1-1.0-II	1 megohm
R10-32	Resistor WS-1-1-1.0-II	1 megohm
R10-33	Resistor SP-II-2a-47 A	47 kilohms
R10-34	Resistor WS-2-1-6200-I	6.2 kilohms
R10-35	Resistor WS-2-1-13000-I	13 kilohms
R10-36	Resistor WS-2-1-13000-I	13 kilohms
R10-37	Resistor WS-2-1-3600-I	36 kilohms
R10-38	Resistor WS-2-1-470-II	470 ohms
R10-39	Resistor WS-2-1-470-II	470 ohms
R10-40	Resistor WS-2-1-4700-II	4.7 kilohms
R10-41	Resistor WS-2-1-4700-II	4.7 kilohms
R10-51	Resistor WS-0.5-1-1.0-II	1 megohm
R10-52	Resistor WS-0.5-1-1.0-II	1 megohm
R10-53	Resistor WS-0.5-1-1.0-II	1 megohm
R10-54	Resistor WS-0.5-1-1.0-II	1 megohm
R10-55	Resistor WS-2-1-20000-I	20 kilohms
R10-56	Resistor WS-2-1-20000-I	20 kilohms
R10-57	Resistor WS-0.5-1-0.1-I	100 kilohms
R10-58	Potentiometer, wire-wound, 25 W, 1000 ohms ± 10%	1 kilohm
R10-59	Resistor WS-0.5-1-0.1-I	100 kilohms
R10-60	Resistor WS-2-1-13000-I	13 kilohms
R10-61	Resistor WS-2-1-13000-I	13 kilohms
R10-62	Resistor SP-II-2a-2.2 A	2.2 kilohms
R10-67	Resistor PO-10-1000 ± 10%	1 kilohm
R10-68	Resistor WS-0.5-1-0.51-I	0.51 megohm
R10-69	Resistor WS-2-1-3600-I	3.6 kilohms
R10-70	Resistor WS-0.5-1-0.1-I	100 kilohms
R10-71	Resistor WS-0.5-1-0.1-I	100 kilohms
R10-72	Resistor WS-2-1-10000-I	10 kilohms
R10-73	Resistor WS-1-1-0.47-I	470 kilohms
R10-74	Resistor SP-I-2a-470 A 13 1	470 kilohms
R10-75	Resistor WS-0.5-1-100-II	100 ohms
R10-76	Resistor WS-0.5-1-100-II	100 ohms
R10-77	Resistor WS-2-1-10000-I	10 kilohms
R10-78	Resistor WS-2-1-10000-I	10 kilohms
R10-79	Resistor WS-2-1-10000-I	10 kilohms
R10-80	Resistor WS-2-1-10000-I	10 kilohms
R10-81	Resistor WS-1-1-1.0-II	1 megohm
R10-82	Resistor WS-1-1-1.0-II	1 megohm
R10-84	Resistor WS-2-1-6200-I	6.2 kilohms
R10-85	Resistor WS-2-1-13000-I	13 kilohms
R10-86	Resistor WS-2-1-13000-I	13 kilohms
R10-87	Resistor WS-2-1-3600-I	3.6 kilohms

R10-88	Resistor WS-2-1-470-II	470 ohms
R10-89	Resistor WS-2-1-470-II	470 ohms
C10-1	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF
C10-2	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF
C10-3	Capacitor BM-P-8-4 µF ± 10% 600 V	4 µF
C10-4	Capacitor KBG-MP-2W-600-1.0-II	1 µF
C10-5	Capacitor BM-P-8-4 µF ± 10% 600 V	4 µF
C10-6	Capacitor KBG-MP-2W-600-0.5-II	0.5 µF
C10-51	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF
C10-52	Capacitor KBG-MP-3W-600-2x0.1-II	0.1 µF
C10-54	Capacitor KBG-MP-2W-600-1.0-II	1 µF
C10-55	Capacitor BM-P-8-4 µF ± 10% 600 V	4 µF
C10-56	Capacitor KBG-MP-2W-600-0.5-II	0.5 µF
V10-1	Double triode 6N8S	
V10-2	Double triode 6N8S	
V10-3	Double triode 6N8S	
V10-4	Beam tetrode 6P3S	
V10-5	Beam tetrode 6P3S	
V10-6	Double triode 6N8S	
V10-7	Double triode 6N8S	
V10-8	Double triode 6N6S	
V10-9	Double triode 6N9S	
V10-51	Double triode 6N9S	
V10-52	Double triode 6N9S	
V10-53	Double triode 6N9S	
V10-54	Beam tetrode 6P3S	
V10-55	Beam tetrode 6P3S	
V10-56	Double triode 6N8S	
V10-57	Double triode 6N8S	
V10-58	Double diode 6X6S	
V10-59	Double triode 6N9S	
Tr10-1	Transformer	1V/20V;50 c/s
Tr10-51	Transformer	1V/15V;50 c/s
Dł10-1	Choke	2000 H
Dł10-2	Choke	2000 H
Dł10-3	Choke	19000 H
Dł10-51	Choke	2000 H
Dł10-52	Choke	2000 H
Dł10-53	Choke	19000 H
W10-1	Rotary switch 3P6N	
Pp10-1	Milliammeter M-52	50 mA
Pp10-2	Milliammeter M-52	50 mA
P10-1	Relay	110 V; 50 c/s
P10-2	Relay	110 V; 50 c/s
G10-1	Telephone jack	
G10-2	Telephone jack	
G10-3	Telephone jack	
G10-4	Telephone jack	
G10-5	Telephone jack	
G10-6	Telephone jack	
G10-7	Telephone jack	
G10-11	Telephone jack	
G10-12	Telephone jack	
G10-13	Telephone jack	
G10-14	Telephone jack	
G10-51	Telephone jack	
G10-52	Telephone jack	
G10-53	Telephone jack	
G10-54	Telephone jack	
G10-55	Telephone jack	
G10-56	Telephone jack	
G10-57	Telephone jack	
Zw10-1	Knife-type connector	22-contact
Zw10-2	Knife-type connector	22-contact

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Antenna Control Unit

C12-1	Capacitor FBG-MN-2A-200-4.0-II	4 µF	
C12-51	Capacitor KBG-MN-2A-200-4.0-II	4 µF	
C12-52	Capacitor KBG-MN-2A-200-6.0-II	6 µF	
Tr12-1	Transformer	10/2.5V;50 c/s	
Tr12-2	Transformer	110/21V;50 c/s	
Tr12-3	Transformer	110/2x110V; 50 c/s	
Tr12-51	Transformer	10/2.5V;50 c/s	
Tr12-52	Transformer	110/21V;50 c/s	
W12-1	Switch 3P9N		
W12-2	Double-pole switch		
W12-3	Double-pole switch		Not in the stations of the first series.
E12-1	Interlocking relay	110V; 50 c/s	
E12-51	Interlocking relay	110V; 50 c/s	
M12-1	Selsyn SS-405, class II	110V; 50 c/s	
M12-2	Motor ASM-400	110V; 50 c/s	
M12-3	Motor ASM-50	20V; 50 c/s	
M12-51	Selsyn SS-405, class II	110V; 50 c/s	
M12-52	Motor ASM-50	20V; 50 c/s	
Zw12-1	Connector	16-point	
Zw12-2	Connector	16-point	

Antenna Pedestal

R32-1	Resistor, wire-wound, 0.8 ohms, 6 A	0.8 ohms	
R32-2	Resistor, wire-wound, 0.8 ohms, 6 A	0.8 ohms	
R32-3	Resistor WS-2-1-10000-II	10 kilohms	
R32-4	Resistor WS-2-1-10000-II	10 kilohms	
R32-5	Resistor, tubular, III-500 ohms	500 ohms	
R32-6	Resistor, wire-wound, 51 ohms	51 ohms	
R32-7	Resistor, wire-wound, 51 ohms	51 ohms	
R32-8	Resistor WS-2-1-10000-II	10 kilohms	
R32-9	Resistor WS-2-1-10000-II	10 kilohms	
R32-10	Potentiometer 1000 ohms	1000 ohms	
R32-11	Resistor WS-2-1-4700-II	4.7 kilohms	
R32-51	Resistor, wire-wound, 0.8 ohms, 2.5 A	0.8 ohm	
R32-52	Resistor, wire-wound, 0.8 ohms, 2.5 A	0.8 ohm	
R32-53	Resistor, tubular, III-500 ohms	500 ohms	
C32-1	Capacitor KBG-MN-2A-200-4.0-II	4.0 F	
Z32-1	Filament lamp MN-15	6.3 V	
Z32-2	Incandescent lamp SM-11	11 V	
W32-1	Double-pole switch	2 A; 250 V	
W32-51	Limit switch	250 V	
W32-52	Limit switch	250 V	
P32-1	Relay RKM(10 b)		
P32-2	Relay RKM(10 b)		
P32-3	Relay	127 V	
P32-4	Relay RC-13-40		
P32-5	Relay RC-13-91		
M32-1	Selsyn DI-511, class II	110 V; 50 c/s	
M32-2	Selsyn DI-511, class I	110 V; 50 c/s	
M32-3	Motor MI-12 f	110 V; 50 c/s	
M32-4	Selsyn SS-405, class II	110 V; 50 c/s	
M32-5	Selsyn SS-405, class I	110 V; 50 c/s	
M32-6	Tachogenerator GT-1		
M32-7	Motor-reference voltage generator set	1400 r.p.s.	
M32-51	Selsyn DI-511, class II	110 V	
M32-52	Selsyn DI-511, class I	110 V	
M32-53	Motor MI-12 f	110 V	
M32-54	Selsyn SS-405, class II	110 V	

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M32-56	Tachogenerator GT-1		
P⫨32-1	Terminal block	12-contact	
P⫨32-2	Terminal block	12-contact	
P⫨32-3	Terminal block	12-contact	
P⫨32-4	Terminal block	12-contact	
P⫨32-5	Terminal block	12-contact	
P⫨32-7	Current collector	35-point	
P⫨32-8	Terminal block	24-contact	
P⫨32-9	Terminal block	15-contact	
D32-1	Selenium rectifier WS-45-28		
D32-2	Selenium rectifier WS-45-28		
Zw32-1	Connector with cap	2-contact	
Zw32-1	Knife-type connector	22-contact)	Not in the stations of the first series.
Zw32-2	Knife-type connector	22-contact)	

Power Pack of Drive Motor Field Winding

R66-1	Resistor WS-2-1-10000-II	10 kilohms	
R66-2	Resistor WS-2-1-10000-II	10 kilohms	
R66-3	Resistor WS-2-1-10000-II	10 kilohms	
V66-1	Kenctron 5C3S		
Tr66-1	Transformer	110/2x400/5 V; 50 c/s	
B66-1	Fuse	5 A	
B66-2	Fuse	5 A	

Data Transmission System

Receiving Selsyn

Z44-1	Filament lamp MN-15	6.3 V	
Z44-2	Filament lamp MN-15	6.3 V	
W44-1	Switch 3P9N		
W44-2	Double-pole switch	2 A, 250 V	
W44-3	Double-pole switch	2 A, 250 V	
W44-4	Double-pole switch	2 A, 250 V	
M44-1	Selsyn SS-404, class I	110 V; 50 c/s	
⫨44-1	Terminal block	4-terminal	
⫨44-2	Terminal block	12-terminal	
M44-2	Selsyn SS-404, class I	110 V; 50 c/s	

External Board

Z33-01	Filament lamp	6 V	
Z33-02	Filament lamp	6 V	
W33-01	Switch		
W33-02	Switch		
P⫨33-01	Terminal		
P⫨33-02	Terminal		
P⫨33-03	Terminal		
P⫨33-04	Terminal		
P⫨33-05	Terminal		
P⫨33-06	Terminal		
P⫨33-07	Terminal		
P⫨33-08	Terminal		
P⫨33-09	Terminal		
P⫨33-10	Terminal		
P⫨33-11	Terminal		
P⫨33-12	Terminal		
P⫨33-13	Terminal		
P⫨33-14	Terminal		
Zw33-01	Connector	8-blade	
Zw33-02	Connector	16-blade	

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Zw33-03	Connector	16-blade	
Zw33-04	Connector	12-blade	
Zw33-05	Connector	16-blade	
Zw33-06	Connector	16-blade	
Zw33-07	Adapter		

Power Supply System

Control Cabinet

Z31-1	Dial lamp MN-15	6.3 V;0.28 A	
Z31-2	Dial lamp MN-15	6.3 V;0.28 A	
M31-1	Timer SD-2		
P±31-1	Terminal block	10-contact	
P±31-2	Terminal block	6-contact	
P±31-3	Terminal block	4-contact	
P±31-4	Terminal block	4-contact	
P±31-5	Terminal block	4-contact	
P±31-6	Terminal block	2-contact	
Zw31-1	Connector		
Zw31-2	Connector		
Pp31-1	Voltmeter E-421	0 - 250 V	
Pp31-2	Voltmeter E-421	0 - 150 V	
W31-7	Switch PKS3-15	220 V, 15 A	
W31-8	Switch PKS2-15	220 V, 15 A	
W31-9	Switch PKS3-15	220 V, 15 A	
W31-1	Start button	220 V, 50 c/s	
W31-2	Start button		
W31-3	Control button		
W31-4	Start button	110 V,427 c/s	
W31-5	Start button		
B31-1	Fuse	25 A	
B31-2	Fuse	25 A	
B31-3	Fuse	25 A	
B31-4	Fuse	15 A	
B31-5	Fuse	15 A	
B31-6	Fuse	15 A	
B31-7	Fuse	15 A	
B31-8	Fuse	15 A	
B31-9	Fuse	5 A	
B31-10	Fuse	5 A	
B31-11	Fuse	15 A	
B31-12	Fuse	15 A	
P31-1	Relay (contactor)	220 V; 50 c/s	
P31-2	Relay (contactor)	220 V; 50 c/s	
P31-3	Thermal relay TRW-30.5	30.5 A	
P31-4	Thermal relay TRW-30.5	30.5 A	
P31-5	Thermal relay TRW-30.5	30.5 A	
P31-6	Thermal relay TRW-30.5	30.5 A	

Control Panel

R13-1	Resistor WS-1-1-270-II	270 ohms	
Tr13-1	Transformer	33/2x100 V; 24 c/s	
Tr13-2	Transformer	33/2x100 V; 24 c/s	
Tr13-3	Transformer	220V/110V; 50 c/s	
W13-1	Push-button switch KS-1-12		
W13-3	Switch PK-2-10		
W13-4	Switch PK-2-10		
W13-5	Switch PK-3-10		
W13-6	Switch PK-3-10		

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W13-7	Rotary switch 3P9N		
D13-1	Selenium rectifier WS-45-28		
D13-2	Selenium rectifier WS-45-28		
P13-1	Magnetic starter MPKO-111	220 V; 50 c/s	
P13-2	Magnetic starter MPKO-111	220 V; 50 c/s	
P13-3	Thermal relay TRW-12		
P13-4	Thermal relay TRW-12		
P13-5	Thermal relay TRW-12		
P13-6	Thermal relay TRW-12		
M13-1	Motor AOL-21-2	220 V	
B13-1	Fuse	5 A	
B13-2	Fuse	5 A	
B13-3	Fuse	5 A	
B13-4	Fuse	5 A	
B13-5	Fuse	5 A	
B13-6	Fuse	5 A	
B13-7	Fuse	25 A	
B13-8	Fuse	25 A	
B13-9	Fuse	10 A	
B13-10	Fuse	10 A	
B13-11	Fuse	10 A, 220 V	
B13-12	Fuse	5 A, 220 V	
B13-13	Fuse	5 A, 220 V	
B13-14	Fuse	5 A, 220 V	
Pł13-1	Terminal block	4- contact	
Pł13-2	Terminal block	12-contact	
Pł13-3	Terminal block	12-contact	
Pł13-4	Terminal block	12-contact	
Pł13-5	Terminal block	12-contact	
Pł13-6	Terminal block	12-contact	
Pł13-7	Terminal block	4-contact	
Pł13-9	Terminal block	12-contact	
Pł13-10	Terminal block	12-contact	
Zw13-1	Connector	22-contact	

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.../Symbols Lists

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Symbols List of Components

Russian Symbols	Latin Symbols	Name of Component
Л	V	Valves and Tubes
НЛ	N	Neon Lamps
ЛН	Z	Filament Lamps
R	R	Resistors
C	C	Capacitors
L	L	Coils
Тр	Tr	Transformers
Др	Dl	Chokes
В	W	Switches, relays, buttons, interlocks
Н	Pp	Measuring Devices
Кв	Kw	Crystals
Д	D	Detectors and Rectifying Components
Р	P	Relays and Contactors
М	M	Electric Machines (Motors, selsyns)
Фв	Fp	Phase Shifters
Т	T	Telephones (Hard Sets)
	Mk	Microphones
РИ	Is	Spark-gaps
А	A	Antennae
Пр	B	Fuses
Б	Bat	Batteries
Г	G	Single Jacks
Б	Zw	Plug-in Connectors
Ф	Zk	Co-axial connector (to echo box)
И	I	Insulators
Э	Z	Earthings
Л	Ŀ	Terminal Blocks and Panels
У	U	Permanent magnets, special systems and devices
Э	E	Electromagnets
Кп	Pl	Terminal panel (block)
ОР	Rez	Echo box
Я	W	Rotor terminals
Б2-1,; конт 6	Zw2-1 Contact 6	
С2-21	C2-21	
Л1-14, конт 4	V1-14 Contact 4	
Тр3-2, конт 4	Tr3-2 Contact 4	
В2-1	W2-1	
L3-4	L3-4	
М4-2	W4-2	
Г6-1	C6-1	
Др6-1	Dl6-1	
8-13А	R8-13A	
8-13	R8-13B	
Кп25-1, конт 3	Pl25-1 Contact 3	
ом	Ohm	
Ком	Kilohm	
Мгом	Megohm	
Р25-1	P25-1	
ЭМУ	WEM	Amplidynes

.../WLU-2

Russian Symbols	Latin Symbols	Name of Component
ВЛУ-2	WLU-2	Valve Voltmeter
ПБ25-1	PB25-1	
РР-5	ZG	Discharge valve
БР-1	BP-1	
6К4	6Z4	
КТ	KT	
ВН13-1	D13-1	Rectifying component
6Н8С	6N8S	
6П3	6P3	
6П9	6P9	
6Х6С	6H6S	

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